USF 85

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RADIOLOGICAL SAFETY MANUAL

1947

USF 85

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2. This publication has a direct relationship to other tactical, operational, and training publications and should be used in conjunction with them.

3. Recommendations for changes in USF 85 to meet future requirements are solicited. They shall be forwarded to the Chief of Naval Operations via the chain of command.

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FOREWORD

1. The Radiological Safety Manual USF 85 is issued to provide the Operating Forces all the basic information, of that presently available, which is considered necessary to gain and maintain standards of Operational Readiness.

2. In Order to keep the classification of the material contained in the manual to no higher than Confidential and thus to permit reasonably wide dissemination, much of the material reviewed in its compilation was rejected or edited to insure against violation of security. Damage and casualty radii although inexact are sufficiently representative to form a basis for effective training.

3. This publication is based upon Hiroshima and Nagasaki results as well as upon postwar CROSSROADS Tests. Expert opinion has not yet crystallized upon all implications of Atomic Warfare. Laboratory experiments and theory may be expected to progress, thus making Radiological Safety a continually changing science. Operational training drills and exercises are expected to result in recommendations for improvement in tactics and techniques.

4. This manual presupposes that all officers are familiar with other basic tactical and damage-control publications and that the contents herein will be integrated with, rather than supercede, those manuals.

5. This manual is divided into chapters, the chapters into sections, and sections into paragraphs. Chapters are designated by Roman numerals with the sections and paragraphs indicated by three-digit numbers for convenience in reference and signal. The first digit indicates the chapter, the second digit the section within the chapter, and the last digit indicates the paragraph. Where further subdivision has been necessary, those subdivisions are indicated by lower case letters and arabic numerals.

6. Recommendations for changes to USF 85 shall be forwarded to the Chief of Naval Operations via the chain of command.

7. The issue of temporary addenda to augment the exercises contained herein or the issue of additional exercises by fleet, type or training commands is authorized to meet the training requirements.

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CHAPTER I

100. General

110. The objective of the Manual is to provide the Operating Forces with a basis for readiness in radiological safety by:

(*a*) Acquainting all personnel with the hazards that may be expected.

(*b*) Setting forth currently accepted methods of detection.

(*c*) Setting forth currently accepted methods of decontamination.

(*d*) Providing an operational instruction program and basic operational exercises in detection and decontamination.

111. Definition of Radiological Safety.

Radiological Safety is the means to control damage from radioactivity. It includes:

(*a*) Preliminary measures to prevent damage such as:

(1) Training, organization and distribution of personnel.

(2) Development, provision and maintenance of fixed and portable material.

(*b*) Measures following release of radioactive matter such as:

(1) Use of detecting equipment.

(2) Protection and/or removal of exposed personnel.

(3) Decontamination of personnel, equipment, structure or terrain.

120. Essentials extracted from CNO Confidential Letter Op34E6/ab (SC) P11-1 Serial O756P34 of 29 September 1947 along with relevant comments pertaining to radiological safety training within the fleets follow in subparagraphs 121 through 126.

121. Fleet Commanders are directed to establish in each ship of the active fleet an organization for handling shipboard radiological safety. Except for some techniques of detection and decontamination, the principles associated with radiological safety are identical with those of chemical-warfare defense. They consist essentially of physical protection of personnel and physical removal of the agents. Therefore, as a matter of policy, it is directed that initially the "RadSafe" organization be a part of the ship's damage-control organization.

122. Specially trained personnel sufficient to man these organizations will be available only in limited numbers far below requirements. However, by the end of 1947, there will be available to all ships, information and instructions appropriate for self-training of officers and for the instruction of enlisted men.

123. Instruments for detection of hazards will not be available until 1948 or later. The present designs are delicate of construction, limited in application, and unsuited for general shipboard use. They are undergoing redesign and will be produced in quantity as soon as the prototype models have been evaluated. Present designs are described in chapter III.

124. Because of the above factors, training initially will lack realism. However, since there is an operational requirement for Navy-wide ability to handle this problem, it is necessary that organization and training be started as early as practicable.

125. Responsibility for radiological safety training and inspections parallels responsibility for all other training.

126. In order that responsible commanders may plan effective interim and ultimate organization and readiness, the following information relative to personnel and sources of information is given:

(*a*) Officers who graduate from special postgraduate courses in radiological safety will be ordered to senior staffs to act as advisors in radiological matters. These specially qualified officers will be designated by BuPers as "RadSafe Engineers." Until RadSafe Engineers are available, these duties may be performed by graduates of shorter courses.

(*b*) The officer in each ship who heads up the RadSafe organization will be designated by the Commanding Officer as the "RadSafe Officer." When practicable, this officer will be a graduate of the 6 weeks' Radiological Safety Officer course conducted by BuPers or of a similar course conducted by the Army using an identical curriculum and for which quotas are being granted to the Navy. The RadSafe Officer may be the Engineer Officer, the Damage Control Officer, or another officer, but in the latter case he will function under the Damage Control Officer and hence the Engineer Officer whose senior responsibilities relative to prevention and control of all damage remain unchanged. Except as governed by the availability of quotas, Commanding Officers are not restricted as to the number of officers qualified by special courses nor are they limited in the number which they may have undergoing self-training. It is conceivable that large units may require several officers to gain competence in radiological safety.

(*c*) RadSafe Monitors will be required as an integral part of the RadSafe organization. They will become qualified in the use of detection equipment and in decontamination procedures. Ultimately all repair party personnel should be so qualified. Their training must be conducted on board by the RadSafe Officer using instructional material similar to that outlined in subparagraph (*e*) below. Consequently chapter V of this publication contains a proposed shipboard course of instruction to produce the necessary qualifications.

(*d*) When detection equipment is allocated and on board, maintenance personnel other than the regular complement of electronics repair personnel will not be required. The circuits of radiological detection instruments are relatively simple when compared with those customarily maintained by ETM ratings.

(*e*) Sources of information dealing with radiological safety which are now available or which will be published during the current year are:

(1) **The Joint Crossroads RadSafe Manual** (available in Dec. 1947) will be a detailed, technical, and advanced manual. It will contain information which exceeds the scope of fundamental details required for operational purposes and is designed as a basic source book for other publications. It is usable as a text in schools.

(2) The Bureau of Naval Personnel has distributed the following:

(i) A special issue of **All Hands** magazine (July 1946) containing a simplified, concrete summation of the principles of nuclear physics used in the development of the atomic bomb.

(ii) A correspondence course in Nuclear Physics (Nov.-1946).

(iii) Copies of the **Smyth Report.**—A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government 1940–45 (1946).

(3) Within their respective areas of cognizance, the Bureau of Ships and the Bureau of Yards and Docks may be expected to distribute instructions on protection, the operation of detection equipment, and on decontamination as developed and as appropriate.

(4) The Bureau of Medicine and Surgery has been directed to disseminate instructions on the medical aspects of radiological safety as appropriate. The Bureau of Medicine and Surgery is responsible for all basic and technical training of medical personnel as individuals. Special training of Radiological Health Officers is in the planning stages. This and the necessary instruction of all medical personnel to cope with radiological safety may be expected to progress in accordance with an orderly program.

130. Security Restrictions.

By an act of Congress, all control of atomic energy and direct subsidiary activities, such as safety pertaining to radioactive materials, is vested in the Atomic Energy Commission (AEC). Although the military branches of our Government must premise preparedness on the fact that information dealing with atomic energy is not exclusively the property of our own and friendly governments, there are, in this field, many data vital to national security. All information dealing with this subject, its background, its scientific aspects, and its implications from a military or naval standpoint must be given clearance by the AEC prior to release.

140. General Information re Bomb Bursts.

141. Eyewitnesses in Hiroshima were agreed that they saw a blinding white flash in the sky, felt a rush of air, and heard a loud rumble of noise, followed by the sound of rending and falling buildings. All spoke of the settling darkness as they found themselves enveloped by a thick cloud of dust. The action of the bomb can best be explained by the analogy of the destruction expected to a model town built to the scale of Gulliver's Lilliput, 1 inch to 1 foot, if there were exploded above it a bomb more than twice as large as the largest "blockbuster." A more complete summary of the action of the bomb is set forth in chapter II.

142. There have been five atomic bomb bursts to date:

(*a*) Alamorgordo, New Mexico, trial burst 16 July 1945, air burst above ground.

(*b*) Hiroshima, Honshu, Japan, 6 August 1945, air burst above ground.

(*c*) Nagasaki, Kyushu, Japan, 9 August 1945, air burst above ground.

(*d*) Bikini, Marshall Islands, Operation CROSSROADS Test Able, 1 July 1946, air burst above water.

(*e*) Bikini, Marshall Islands, Operation CROSSROADS Test Baker, 25 July 1946, underwater detonation.

143. Although Radiological Safety Training is based on the experience gained from the five atomic bursts to date, it is obvious that variations may occur in future detonations. These variations may be:

(*a*) The altitude or depth of the burst could be such that:

(1) A different combination of effects from those previously experienced will result. More specifically, should the burst be placed slightly above or below the surface of the water, a combination of the outstanding effects of Bikini Tests Able and Baker may result.

(2) A deep-water detonation, such as that proposed for the canceled third Bikini test, would produce effects that can only be visualized in theory.

(*b*) The method of delivering the bomb may be different. Possibilities are:

(1) Aircraft, for ranges of thousands of miles.
(2) Guided Missiles, for ranges of a few hundred miles.
(3) Clandestine (Trojan Horse), for seaports, canals, and airports.
(4) Clandestine, sabotage.
(5) Torpedo.
(6) Mine.

(*c*) The bomb efficiency achieved to date may be improved upon or may not be attained by foreign manufacture. In fact, the possibility of an enemy producing an identical bomb is quite remote.

(*d*) There exists the possibility of using radioactive agents without a detonation.

150. Tactical Implications.

The tactical implications of Atomic Warfare and Radiological Safety are not firm and therefore no specific tactical training program is set forth in chapter V (Training). There are, however, some known significant factors that may contribute to sound decisions by Tactical Commanders and by Commanding Officers and which may lead to the development of good tactical procedures. These factors are:

151. Increased distances and intervals may be used to minimize the effects of each bomb delivered if the following conditions obtain:

(*a*) Available and reliable intelligence bearing upon the probability of Atomic Attack employing any of the methods of delivery listed in paragraph 143 (*b*) above has been considered and results affirmatively.

(*b*) Effectiveness of own control of the air and own screening measures against the several methods of delivery has been evaluated as inadequate.

(*c*) The consequent reduction in fire concentration will not result in failure to accomplish the assigned mission or outweigh the gain in safety.

152. Generally advisable, but not conclusively nor invariably so, are the following procedures relative to distance and interval:

(*a*) For fast carrier task groups with adequate air and screening support: no change, or not more than 3,000 yards between heavy units.

(*b*) For anchorages:

(1) Sortie as practicable.

(2) Berth heavy valuable units no closer together than 4,000 yards.

(3) If necessary, assign intervening berths to light units, otherwise maintain 4,000 yards between all units.

(*c*) For convoys: Increase distances and intervals to not less than 3,000 yards and to 4,000 yards if screen effectiveness is not reduced over 50 percent thereby.

(*d*) For amphibious operations: Keep heavy valuable units as well separated up to 4,000 yards as consistency with mission accomplishment permits, filling intervals as necessary with ligher units.

153. Tolerance dosages of radiation may be exceeded somewhat without fatal or serious effect. Radiation is measured by a unit called a roentgen (r). One-tenth of one roentgen per day (0.1 r/day) is the established national standard tolerance which will inflict no deleterious effect whatsoever even if such exposure is habitual. On the other hand, it is known that several hundred r is fatal and that various degrees of permanent ill effects are inflicted proportionately by various lesser amounts. Results of animal tests of Operation CROSSROADS will be promulgated when complete and with appropriate security classification. As in subjecting his units to enemy gunfire, the calculated risk vs. the probable gain by exceeding tolerance dosages will be a matter for decision by the O. T. C. No medical authority has yet expressed a maximum nonfatal dosage; however, the following table indicates total body irradiation exposure-effect ranges agreed upon by some medical authorities:

0.1 r/day	Maximum medico-legal peacetime exposure.
0.1 to 10	Relatively little risk.
10 to 25	Some injury likely but probably not incapacitating.
25 to 100	Injury practically certain, probably incapacitating.
100 to 300	Serious injury, some deaths practically certain but may be delayed.
300 to 600	Serious injury or deaths certain, very serious incapacitation, some may linger for weeks or months requiring extensive medical attention and even then die.
600 to 1,000	Death certain, usually in first 24 hours.
Above 1,000	Death certain, usually in a few hours.

154. Radiation effects are not always immediately noticeable. In infrequent cases of lethal dosage, nausea may set in within fifteen minutes to one hour after exposure. This may disappear and no effects be noticed for several days when gradual weakness may develop and death eventually occur. In emergencies, exposed personnel may continue their normal functions for many hours before the effects are discernable. However, personnel monitoring should be the first step after radiation exposure has been a possibility and if tolerance dosage has been exceeded, evacuation, decontamination, and special treatment by competent medical personnel should follow at once.

155. Prompt action by conning officers can be taken to keep contamination at a minimum by using rudder and engines to avoid cloud fall-out, base surge and/or contaminated areas.

(a) Cloud fall-out from a water burst first falls to the surface outside the column 10 to 20 seconds after the column forms and immediately diffuses vertically to a depth of about five feet. Subsequent diffusion downward is at a rate of about ten feet per five minutes. Sea suction fifteen feet below the waterline thus may not become contaminated for several minutes and the possibility of gaining uncontaminated sea water for decontamination and for fire fighting might be realized from outside of several hundred yards at the time of the burst if prompt rudder action is taken. Horizontal water diffusion is much slower than any normal ship speed.

(b) Although the radioactive base surge initially rolls out from the foot of the water burst column at high speed, it soon slows appreciably so that avoidance may be achieved near the edge of its effective area by prompt action of ship control personnel.

156. Rescue in connection with contaminated ships indicates the need of continued emphasis in the techniques of evacuating personnel by the alongside method. Whereas formerly ships were abandoned only because of uncontrollable fire, loss of buoyancy and/or loss of stability, abandonment may now be necessary because of excessive contamination. Unless an uncontaminated area has been gained, little profit and possibly increased hazard may result from personnel entering the radioactive water. Getting the ship out of the contaminated area may require expeditious towing, another phase of seamanship which has been given increased importance by this type of warfare.

160. The study of Radiological Safety, like the study of any new subject, involves a new "language." Certain elementary terms frequently used in this field but not previously in common naval usage, follow. Definition of them is brief. For more complete definition, reference to the special July 1946 issue of **All Hands** magazine or to any good text on Nuclear Physics is recommended.

(a) Terms relating to Radiological Safety:

Alpha (α) Particle.—A positively charged nuclear particle emitted by certain naturally radioactive substances like uranium and radium. The alpha particle has been found to be identical with the nucleus of the helium atom which consists of two protons and two neutrons.

Amplification.—As related to detection instruments is the process, either gas, electronic or both, by which ionization effects are multiplied to a quantity suitable for measuring.

Atom.—The smallest division of an element that can enter into a chemical change. It consists of a central nucleus surrounded by one or more electrons rotating about the nucleus in definite orbits.

Beta (β) Particle.—A negatively charged particle emitted by certain radioactive substances. The beta particle is a high-speed electron having energies such as would be obtained by accelerating an electron by a potential of from ten thousand to several million volts. While beta particles are emitted by the nucleus it is believed that they are created (and immediately emitted) by a transformation in the nucleus.

Cathode.—The negative electrode. The electrode to which positive ions are attracted. (The anode is the positive electrode to which the negative ions are attracted.)

Chain Reaction.—A term applied to any chemical or nuclear process in which some of the products of a particular change assist the further occurrences of that change.

Critical Size.—In respect to atomic energy, critical size is the minimum amount of material which will support a chain reaction.

(a) Terms relating to Radiological Safety—Continued.

Decay.—The disintegration of the nuclei of an unstable element due to the spontaneous emission of charged particles or energy quanta. Elements which decay are called radioactive.

Densitometer.—Instrument utilizing a photoelectric cell for determination of the degree of opacity of developed photographic film.

Density.—The compactness of matter measured in terms of mass per unit volume.

Dosimeter.—This instrument, about the size of a fountain pen, is used to detect and measure accumulated dosage of radiation. It utilizes the principle of the electroscope such that radiation neutralizes the charge on the quartz fibers causing collapse of the fibers.

Electrode.—An electrical conductor inserted into a liquid, solution or gas.

Electron.—The smallest known particle having a negative electric charge. The part of the atom outside the nucleus is made of electrons, the number of which, being equal to the protons in the nucleus, is the same as the atomic number of the atom.

Electron Volt.—The energy given to an electron by a potential difference of one volt and so by definition, is in reality a unit of energy rather than of potential. It is designated by e. v. and 1 e. v.$=1.6\times10^{-19}$ joules$=1.6\times10^{-12}$ ergs. 1 Mev$=1.6\times10^{-6}$ ergs.

Element.—One of the basic kinds of matter from which all chemical compounds are formed.

Energy.—The capacity for doing work.

Fission.—A peculiar kind of disintegration of an atomic nucleus. The nucleus upon being struck by a neutron becomes unstable, breaks into two main fragments which are nuclei of elements of medium atomic weight and emits several free neutrons. The atomic nuclei produced as fragments and the several neutrons rush apart at high speed from the point where fission occurred.

Fission Products.—The elements produced by fission. Those having atomic numbers ranging from 30 (Zn) to 64 (Gd) and which are in most cases radioactive.

Frequency.—The number of cycles of a wave motion completed in a unit time.

Gamma (γ) Ray.—A non-material short wave radiation emitted by some radioactive atoms. Since these rays are electromagnetic radiations, they are not deflected by electric or magnetic fields as particles would be deflected. The gamma ray differs from other electromagnetic radiations in that it comes from transformations taking place within the nucleus of the atom rather than from the electrons outside the nucleus which are the source of light and X-rays. The gamma ray has a high frequency, high penetrability, and moves as a wave motion at the speed of light.

Geiger-Muller Counter.—A radiation measuring device using a high voltage source to amplify the ionization produced by the radiation.

Half-Life.—The rate at which radioactive materials decay is measured by time intervals, called half-life; in the first half-life, the amount of radioactive material left unchanged is one-half the original amount; in the next half-life interval, half the remaining amount or one fourth the original amount remains. The half-life of different materials varies widely—from several billion years to millionths of a second.

Ion.—An atom bearing an electrical charge caused by a temporary excess or deficiency of electrons.

(a) Terms relating to Radiological Safety—Continued.

Ionization.—The process by which an atom which is ordinarily electrically neutral acquires an electric charge.

Isotopes.—Two or more forms of the same element differing slightly in atomic weight, but having the same chemical properties. All isotopes of a given element have the same atomic number or nuclear charge. The nuclei of all isotopes of a given element have the same number of protons, differing only in the number of neutrons. Most chemical elements occur as a mixture of several isotopes, i. e., as a mixture of atoms which are alike in chemical properties but fall into several groups according to weight. Certain isotopes are unstable or radioactive and through spontaneous emission, will give off small particles and/or high frequency electromagnetic radiations changing the isotopes to a stable isotope of the element or a different element.

Mass.—The quantity of matter of a body.

Neutron.—A nuclear particle with no electrical charge but with a mass approximately the same as that of the proton.

Nucleus.—The central part of the atom which makes up most of the weight of the atom. An atomic nucleus is made up of two kinds of fundamental particles, protons and neutrons. It has a positive charge equal to the number of protons it contains.

Photoelectric effect.—The emission of electrons from a substance by the action of radiant energy being absorbed by the substance.

Proton.—A nuclear particle with a positive electric charge equal numerically to the negative electric charge of the electron. The mass of the proton is 1,820 times greater than that of the electron.

Quanta.—All of the components of the electromagnetic spectrum exhibit wave properties, however, as a result of experimental evidence, these radiations are not a smooth, continuous flow of energy as pictured by the wave theory, but are rather a series of discontinuous packages of energy. The energy in each package, which is known as a *photon* or *quantum*, increases with the frequency of the radiation.

Radiation (Ionizing).—Radiation which produces ionization directly or indirectly. It includes: alpha α, beta β, gamma γ, X-ray and neutrons.

Radiation (Nonionizing).—Radiation which does not produce ionization. It includes infrared, ultraviolet and visible light.

Radioactivity.—A property of certain elements which causes their atomic nuclei spontaneously to disintegrate, gradually transmuting the original elements into stable isotopes of that element or into another element of different chemical properties. The process is accomplished by the emission of one or more radiations, such as alpha particles, beta particles, gamma rays or positrons.

Roentgen.—The unit of electromagnetic radiation which will produce one electrostatic unit (e. s. u.) of ions in a cubic centimeter of air under standard conditions of temperature and pressure. One electrostatic unit of charge is 2×10^9 ion pairs.

Wave Length.—This is the distance between any two similar points of any two consecutive waves and is conventionally designated by the Greek letter lambda (λ).

CHAPTER II

200. Nature of the Hazards.

210. Phenomena of the Detonation.

211. An ordinary explosion, such as that of TNT or gunpowder, consists of a flash of fire, a blast with the accompanying sound, and the generation of smoke. These explosions are the results of violent chemical reactions. In other words, the atoms of the elements which make up the explosive are torn loose from each other and recombined and rearranged to form entirely different compounds with the evolution of intense heat. Specifically, certain materials are burned extremely fast, the oxygen being provided by and taken away from one of the components of the explosive. The sensory evidences of explosion are present in an atomic detonation but the degree to which they may be observed is so great that they are almost beyond comprehension. Furthermore, these effects, perceptible to the senses, represent only a part of the total energy given off by an atomic bomb burst. Other energy emissions can be detected and measured only by special instruments.

(*a*) The question that arises in the minds of many is "Where does this energy originate?" The answer is that an atomic detonation is not a chemical change but a physical change. In 1905, Albert Einstein formulated an equation which is a simple relationship of the equivalence of mass and energy. His equation, E equals mc^2, states, in words, that if a mass of matter could be converted to energy, the amount of energy released would be equal to the product of mass times the square of the speed of light. By this equation, if one pound of material were consumed by some process so as to give off its equivalent in energy, 3×10^{16} or thirty million billion foot-pounds of energy would result.[1] In the detonation of an atomic bomb, the nuclei of the atoms which comprise the bomb material are split up, or fissioned, to form entirely different elements. In so doing, a certain amount of the material disappears and in its place energy appears in accordance with Einstein's equation. In this process, the energy is released in about a millionth of a second. Thus it can be seen that the consumption of a small amount of material releases a tremendous quantity of energy. The manner in which this energy manifests itself and the actual products of an atomic bomb detonation are illustrated in figure 1 and are described in the succeeding paragraphs.

212. Blast effect.

Whereas common explosions to date have been capable of damaging a portion of a building or ship or, in rare cases, demolishing a whole unit, an atomic bomb burst could engulf and damage whole buildings or ships. Not just one is affected but all within a radius of several hundred yards. The actual pressure at the center of the detonation is estimated at over a million pounds per square inch. This pressure is the result of the high temperatures produced by the detonation and it is immediately followed by rapid expansion and displacement of the surrounding material. There are three well-defined consequences of such a blast:

(*a*) A positive pressure wave, or blast wave, travels from the center of the burst in all directions. It is not a short shock but more like a very strong gust of wind. The duration of the positive pressure pulse is about one-third of a second.

(*b*) A negative pressure, or blast suction phase, follows the blast pressure wave as in any explosion. The blast suction is considerably weaker in force but it lasts several times as long.

(*c*) A secondary shock effect is the outcome of the impinging of the two blasts on a structure. The pulses will be transmitted throughout the stricken object and will be capable of damaging the interiors of ships or buildings, displacing machinery and equipment and injuring persons within.

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[1] $E = mc^2$
$= 1$ pound $(186{,}000$ miles/second $\times 5{,}280$ feet/mile$)^2$.
$= 1$ pound $(9.82 \times 10^8$ feet/second$)^2 = 96 \times 10^{16}$ foot^2 pound/second.^{2}
$= \dfrac{96 \times 10^{16} \text{ foot}^2 \text{ pound/second}^2}{32 \text{ foot/second}^2} = 3 \times 10^{16}$ foot-pounds.

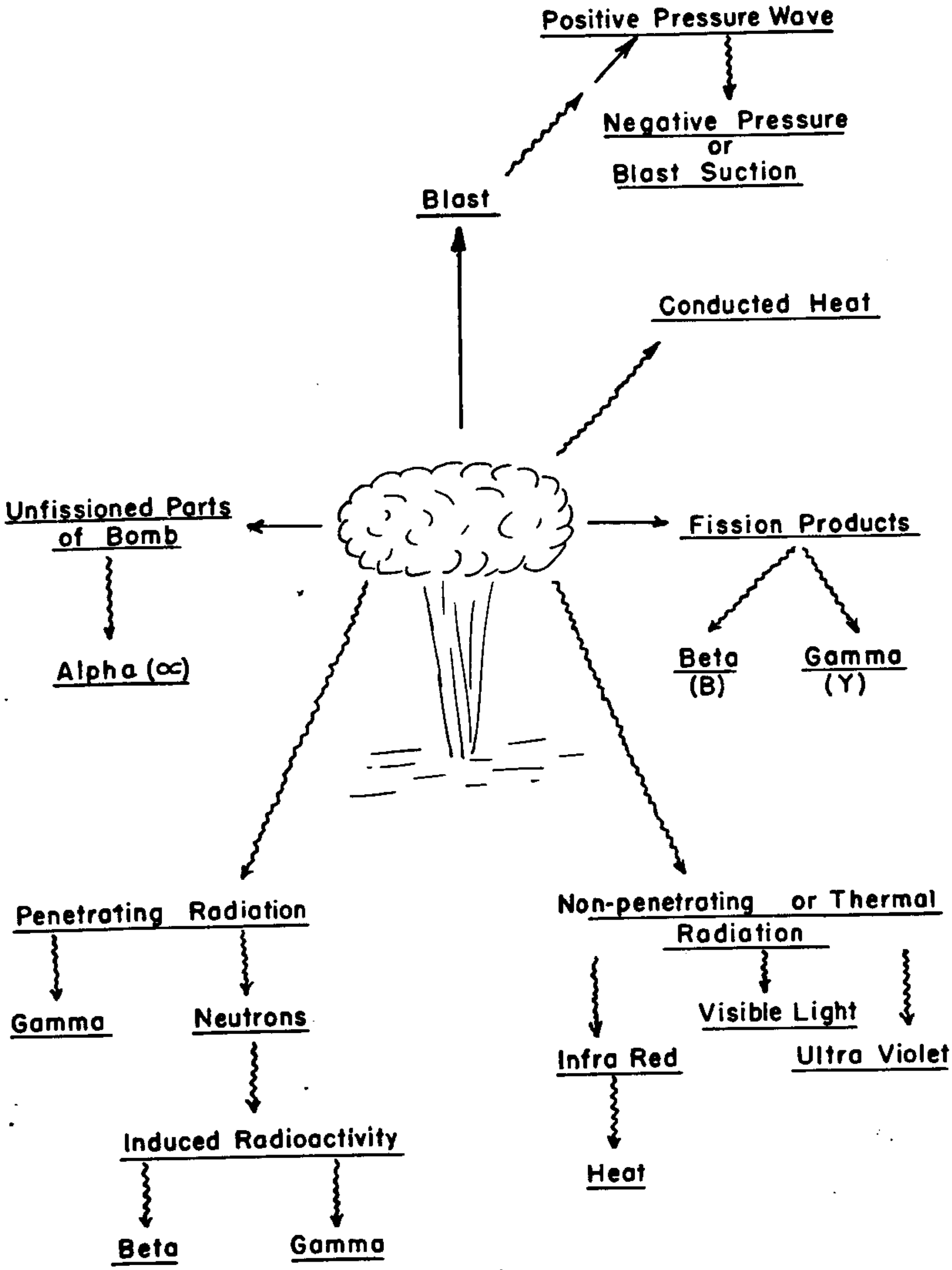

Positive Pressure Wave
Negative Pressure
or
Blast Suction
Blast
Conducted Heat
Unfissioned Parts
of Bomb
Alpha (∝)
Fission Products
Beta
(B)
Gamma
(Y)
Penetrating Radiation
Gamma
Neutrons
Induced Radioactivity
Beta
Gamma
Non-penetrating or Thermal
Radiation
Visible Light
Infra Red
Ultra Violet
Heat

Figure 1.

213. Thermal Energy.

(*a*) Thermal energy constitutes a large percentage of the total energy emission of the atomic bomb detonation. It manifests itself in the form of heat (infra red).

(*b*) The heat is conducted from the exploding bomb to surrounding materials, heating them to incandescence. This first gives the effect known as the "ball of fire," the interior of which reaches temperatures of millions of degrees Centigrade.

214. Other Nonionizing Energy.

(*a*) Other energy emissions are in the form of nonionizing electromagnetic radiation. An electromagnetic radiation is a form of energy transmission by waves such as those used for radio transmission. The family of electromagnetic waves (electric, radio, radar, infra red, visible light, ultra violet, X-rays, gamma rays, cosmic rays) compose what is known as the electromagnetic spectrum (fig. 2). The latter is a graphic representation of the relationship between various types of emanations. The characteristics of the electromagnetic radiations are determined by their respective wave lengths and frequencies. As can be seen in the diagram, high frequency radiations will have short wave lengths. Furthermore, the highest frequencies transmit the most energy per quantum. The frequencies up to and including ultra violet rays are classed as non-penetrating and the following types in this category are emitted from the atomic bomb detonation: Infra red, visible light and ultra violet light. These are also classed as nonionizing radiations.

(*b*) As the name non-penetrating radiation implies, very thin shielding gives good protection from these forms of energy.

215. Radioactivity.

The elements which compose the universe are found in various forms, or isotopes. All isotopes of an element have the same chemical properties, but slight variations in the atomic nuclei cause them to have slightly different weights. Certain unstable isotopes will, through spontaneous emission, give off small particles or high frequency electromagnetic radiations from their nuclei. The fission process also gives off certain of these emissions. These rays and particles, called nuclear radiations, are emitted with very high energies and are capable of ionizing various atoms if they come in contact with them. Ionization is that process in which a particle of molecular size or smaller which is ordinarily electrically neutral, acquires an electrical charge. For example, if a beta particle collides with an oxygen atom and the latter has a negative particle knocked off, it acquires a charge of plus one and is an oxygen ion. Any such positively charged ion together with the electron knocked off (negative ion) are called an ion pair.

(*a*) At the instant of detonation, two penetrating emissions are of importance:

(1) Gamma rays transmit some of the explosion energy. These high frequency, high energy, long range electromagnetic waves are quite similar to X-rays. These rays, originating from the bomb burst, come in two phases. The first is a very intense burst of energy lasting a few milliseconds and resulting from the actual fission process. The other phase is less intense but lasts several seconds. Its origin is the mass of fission products carrying a large fraction of the total gamma energy radiated but having almost infinitessimally short half-lives (i. e., an isotope with a half-life of 2 seconds would have emitted one-half its radiation at the end of 2 seconds; in the next 2 seconds half the remainder of its radiations would be expended and so on.)

(2) In the process of fission, neutrons are shot from the center of the burst at high energies. A neutron is a small uncharged particle which is one of the building blocks of atomic nuclei. They are capable of penetrating heavy thicknesses of steel and several inches of steel will reduce neutron flux by only one half. Thus, neutrons may penetrate deeper into a ship than some gamma rays if the ship is within neutron range. Whereas charged particles ionize the atoms they strike, neutrons are ineffective directly in this ionizing process. However, if they collide with an atom such as hydrogen, they will impart energy to that atom which will in turn produce dense ionization. More-

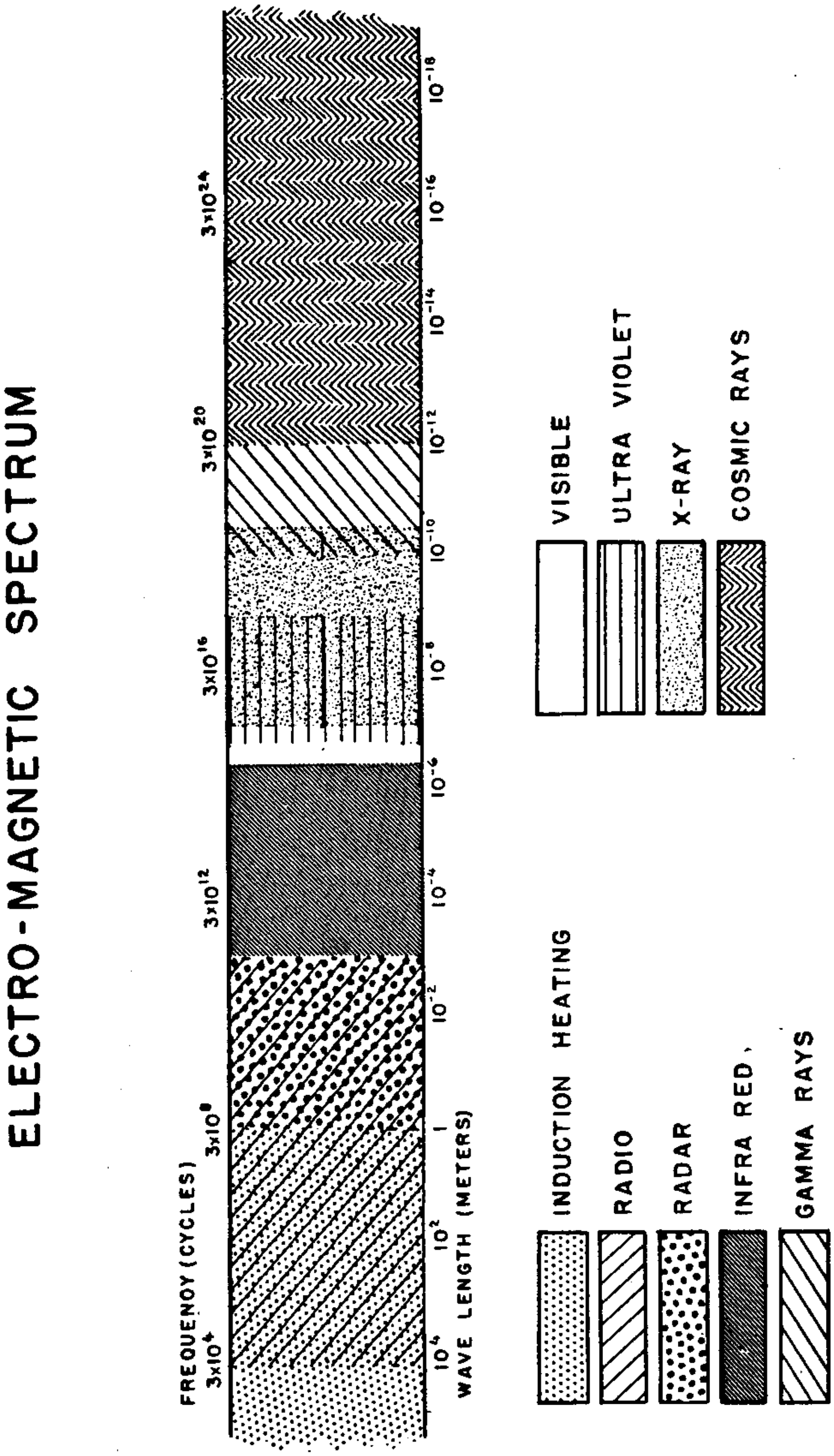

ELECTRO-MAGNETIC SPECTRUM
FREQUENCY (CYCLES)
3x10^4
3x10^8
3x10^12
3x10^16
3x10^20
3x10^24
WAVE LENGTH (METERS)
10^4
10^2
1
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-14
10^-16
10^-18
INDUCTION HEATING
RADIO
RADAR
INFRA RED
GAMMA RAYS
VISIBLE
ULTRA VIOLET
X-RAY
COSMIC RAYS

Figure 2.

over, high energy neutrons are capable of penetrating the atomic nucleus, thus changing its structure. This forms a different isotope of the original or a new element, and this isotope may be an unstable (or radioactive) isotope. To return to stability, the radioactive isotope will give off some form of radiation to reach a balanced condition having a stable nucleus of the same element or of an entirely different element. Materials which are especially susceptible to induced radioactivity are sodium, arsenic, phosphorus, and sulfur.

(*b*) The splitting up of the atoms of bomb material results in the diffusion of minute radioactive particles. The total intensity of these radiations equals that emitted by hundreds of tons of radium.

(1) The bomb efficiency is not 100 percent, so that unfissioned particles of bomb material, either uranium (U 235) or plutonium (Pu), are scattered. Each of these elements is an emitter of alpha particles. An alpha particle is emitted from the nucleus with very high energy but its range in air is only about 4 centimeters. It can be seen that the amount of ionization caused by the alpha particle must be great in relation to distance traveled if such very high energies are dissipated. Only a few elements are known to give off alpha particles.

(2) The fission products are the elements formed when the atoms of U 235 or Pu split. They range in the middle third of the Periodic Table, or from zinc to gadolinium. The unsystematic splitting of the fissionable atoms leaves remnants of more or less unpredictable combinations of protons, neutrons and electrons and which are the fission products. Thus, a wide range of isotopes is formed with the majority of them being radioactive. These isotopes, in decaying to the stable state, emit beta particles and gamma rays with high energies. A beta particle is a high speed electron emitted by an atomic nucleus and its range depends upon its energy and may be as great as 45 feet in air but can be expected to average about 10 feet in air.

220. Physiological effects.

Since the phenomena of detonation are of a varied nature, the resulting physiological effects will be of many types. Casualties resulting from an atomic bomb burst will be the result of one or more actions of the bomb and it is difficult to ascertain which phenomenon is most responsible for any injury. The consequences of each effect of the bomb independent of all others are being studied, although all of the medical aspects are not yet known.

221. The effects of the primary blast wave and the following suction wave are similar to those in any other explosion except in magnitude. However, anyone exposed within lethal blast range would be a casualty from other factors before the blast pulse reached him. The secondary effect is a great source of casualties, as it reached those shielded from the direct blast. The shock which is transmitted is capable of causing injury directly. Displaced or falling structures are an additional hazard.

222. The heat and nonpenetrating radiations are responsible for two types of injuries. The visible light is of such intensity that persons looking directly at an unshielded detonation would be momentarily blinded at a range of several miles. The other consequence consists of burns. Within the range of radiant heat, temperatures may be so great as to char the whole body. Persons not exposed to the fire ball but unprotected from the thermal radiations will have severe burns, ranging from a charring of the skin to mild burns much like severe sunburn. The severe burns are known to affect internal organs as well as the outer skin.

223. The effects of radioactivity on personnel.

(*a*) Alpha emitters are an insidious hazard to personnel. They are difficult to detect and their effect is lasting. These emitters are a primary hazard when absorbed by way of the respiratory system, digestive system or directly into the blood through open wounds. Alpha emitters are distributed by the body in a manner similar to that of calcium; they are carried to the bones, liver, kidneys, etc., and deposited. Constant alpha bombardment of the tissue surrounding this material causes irritation which is not given an opportunity to heal and thus may lead to malignancy. Alpha emitters deposited in the chest or lung cavity may cause cancer of the lungs or chest.

(*b*) Beta emitters are harmful both externally and internally. A large quantity of these materials concentrated near the skin will cause ionization of the tissue and hence skin irritations much like burns. Beta-emitting substances taken into the body have two consequences. In the intestinal tract, beta particles bombarding the walls will cause irritation. Beta emissions kill white blood cells, decreasing resistance to infection.

(*c*) Gamma radiation is the most dangerous type of radioactivity because it has both a long range and a great penetrating power. Its ionizing properties destroy the body cells and upset the normal functions of the body. Low energy gamma radiations cause loss of hair. Light doses may cause nausea and aplastic anemia. As dosage becomes greater, the bone marrow, spleen, and lymph nodes are affected. The marrow of the long bones of the body is affected and the mechanisms which manufacture red and white blood cells are destroyed along with the red blood cells themselves, although the latter are more resistant. Red and white blood cells not destroyed by beta and gamma are depleted through normal functioning of the body and if they cannot be replaced, the natural medium of conveying nourishment and oxygen to the body cells (red corpuscles) and of combating infection (white corpuscles) is lost, thus allowing anemia and disease to go unchecked. Furthermore, a wide variety of hemorrhages is caused by interference with the blood-clotting mechanism. As time is required to deplete the corpuscles, the effects of intense gamma exposure are not evident for about 24 hours (pars. 153–154). Death does not normally occur in less than a week. Fatalities occur upon exposure to a dosage of about 300 roentgens of gamma radiation all over the body though some individuals may have sufficient resistance to receive about 600 roentgens and live. (As previously stated, authoritative medical opinion is not yet firm on these amounts.) Sterility has been noted as a result of gamma irradiation, but experience to date indicates that this is only temporary. Mutations in humans as a consequence of gamma exposure have not been noted as yet, but a relatively short time has passed since persons were subject to this form of radioactivity. Future studies may validate present theories that gamma radiation can result in mutations.

(*d*) Neutron radiation causes intense ionization within the body because of neutron-hydrogen interactions. Neutrons bombarding the body will also induce radioactivity. Phosphorus in the bones is the most susceptible of all body material to induced radioactivity. The penetration of neutrons may change the structure of the atomic nucleus such that the atom, to return to its stable state must emit rays and particles as was explained in paragraph 215 (*a*) (2).

224. Psychological effects.

The psychological aspects of atomic warfare may be based on the bombings in Japan, although differences in race, general point of view, and standards of education will cause distinct variations. In Japan, there was a general panic and break-down of morale after each bomb burst. This occurred after years of strife and hardship which had already put the Japanese people into a sort of lethargy. The American public is somewhat better informed and has knowledge of the existence of this weapon and of its potentialities. We, however, are much less accustomed to hardship. It is to be expected that our military personnel will differ from the Japanese even more due to our being a disciplined body having leadership and standards of action and thought in cases of emergency. The ill effects of a single atomic bomb detonation or of an atomic war will be held to a minimum only through discipline, training, and proper dissemination of information.

230. Consequences peculiar to an air detonation.

231. Description.

The first evidences of an atomic bomb burst in air is a brilliant flash of light lasting a few millionths of a second followed by a seething mass of gases, heated to incandescence, which grows

PERSONNEL DAMAGE
AIR BURST SIMILAR TO HIROSHIMA AND NAGASAKI
PERSONNEL UNSHIELDED EXCEPT FOR CLOTHING

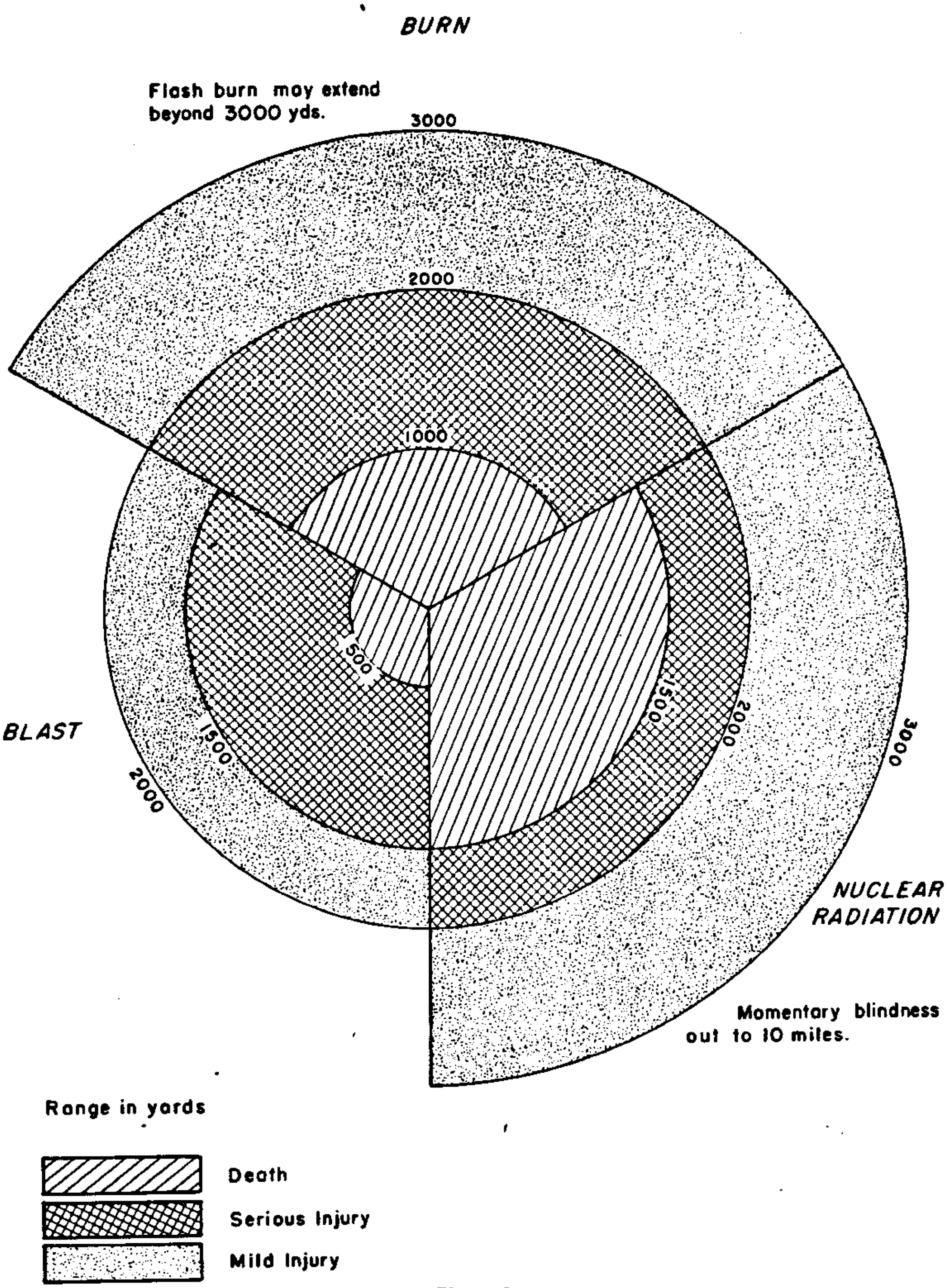


Figure 3.

rapidly to become a large ball of fire. A shock wave travels from the center of the burst, its path visible on the water where it looks like a tremendous surface shimmer traveling in all directions. A condensation cloud appears, caused by the nearly instantaneous expansion of the atmosphere following the passage of the shock wave. The glow of the ball of fire dies out and leaves a great cloud of smoke, fission products, unfissioned particles, and moisture, which ascends rapidly, assuming a mushroom shape and having a peach color. Depending on the atmospheric conditions, such a cloud may rise to 60,000 feet and is shaped as shown in plate I. All data given in succeeding paragraphs are based on previous bombings. It must again be noted that larger bombs or different altitudes of burst will cause variations in the results.

232. Personnel damage with respect to range (fig. 3).

(*a*) Direct blast is a partial factor in causing casualties. For the most part, persons exposed to direct blast alone would probably be killed within 500 yards, but experience has shown that other phenomena will kill most individuals that would otherwise be blast casualties. It may be said that direct blast will aggravate the injuries of radiation casualties having, otherwise, some chance of recovery to such an extent as to cause death.

Secondary effects of blast are of major importance. Persons protected from direct phenomena are in danger of being injured by displaced or falling structures or through pulses transmitted through a ship or building. This one factor contributed most to the casualties in Hiroshima and Nagasaki.

(*b*) Injuries to personnel from nonionizing radiations. The thermal effects of an air burst may be a most serious cause of casualties. The heat radiations are intense and of greater range than any other phenomena.

(1) Persons in the actual ball of fire will most certainly be fatalities, and death could be caused by many factors.

(2) The visible light rays are capable of causing momentary blindness up to a distance of ten miles if an individual is looking directly at the detonation.

(3) The remainder of the thermal radiations will cause severe burns at a great radius. Certain figures based on studies in Japan have been compiled and are given below:

(i) People unsheltered at 500 yards will all be killed.

(ii) At 1,500 yards, severe burns on unprotected skin may be expected. Some severe burns will be evident up to a mile and a quarter. However, Army summer khaki gives ample protection at 1,500 yards.

(iii) At 2½ miles, persons exposed to the direct rays will have mild burns, much like severe sunburn on unprotected skin.

(*c*) Radioactivity.

1. Direct radiations will cause the ultimate death of all persons fully exposed at one-half mile, if other factors were neglected. Some persons within a few hundred yards will be affected by neutron bombardment, but this effect is unimportant except in locations which are well shielded against gamma radiations. The lethal range of gamma rays is about three-fourths of a mile, and from this distance to 1 mile there is a more moderate effect. A British report estimated that a person fully exposed at three-quarters of a mile has a 50 percent chance of survival. The effects drop rapidly beyond 1 mile, with loss of hair being the most serious injury at 1½ miles, though mild radiation sickness may occur at 2 miles.

(2) Contamination is normally carried away from the scene of an air burst in the radioactive cloud and is dispersed into the atmosphere over a large area, thus reducing its effectiveness against personnel. Some fall-out may occur, particularly in the case of a rainstorm in the area, but the intensities will not be great. A burst very near the ground, in which the earth is melted, will cause a greater spread of contamination, as radioactive particles may be fuzed into the molten materials. Some contamination may be blown onto adjacent materials where it will stick. In

STRUCTURAL DAMAGE
AIR BLAST SIMILAR TO HIROSHIMA AND NAGASAKI

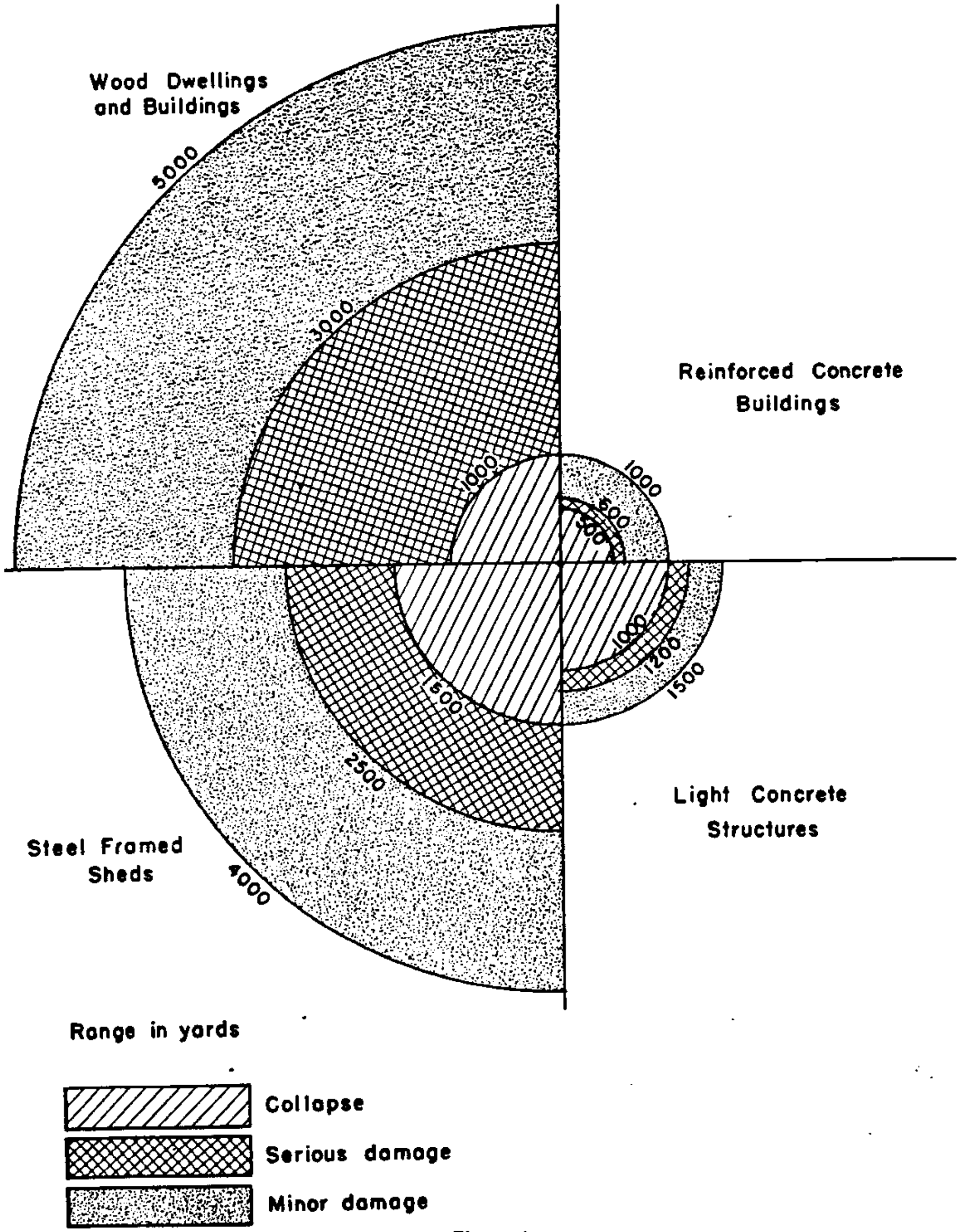


Figure 4.

case the blast is close to water, some contamination will lodge in the water and in steam generated by the heat, creating personnel hazards, but in most cases this will not provide a serious problem.

233. Ship damage from air burst.

Most information on ship damage results from Operation CROSSROADS and is, as yet, highly classified. However, damage may be described in general statements which are adequate for some operational problems.

(*a*) The blast is sufficient to sink any ship afloat if the latter is close enough. A broadside blast can capsize smaller vessels at several hundred yards. Present day bomb types can cause minor damage at 2,000 yards or more. Stacks and flat surfaces are especially vulnerable. Radio and radar antennas are subject to distortion and displacement at greater ranges. The blast wave is capable of funneling down stacks and doing considerable damage to boilers and firerooms.

The secondary shock damage is considerable. All loose gear and that not securely fastened will be displaced within several hundred yards. Light bulbs will be broken, heavy machinery may be displaced and internal members are liable to distortion from the shock transmitted throughout the ship.

(*b*) Thermal radiations are capable of causing material damage over a large area. This radiation is instantaneous, but the amount of heat energy dispersed is sufficient to scorch wood and paint at 1,500 yards or more. Inflammable materials at closer ranges will be ignited, though no record of the exploding of ammunition directly either by shock or thermal energies has been recorded.

(*c*) Induced radioactivity aboard ship may be expected from fairly low altitude bursts. In such a case, the salt water used aboard ship will also be radioactive, both factors reducing the operational readiness of the unit. The materials most susceptible to this phenomenon are listed earlier in this chapter and may be found particularly in such items as salt, baking soda and soap.

234. Land structure damage from an air blast (fig. 4).

The relationship between land-structure damage and range are based on findings in Japan, and it must again be noted that these are special cases. In general, the damage is from two major causes and combinations of the two.

(*a*) The significant feature of blast damage is mass distortion of structure as in damage done by wind of hurricane force. Some effects of suction have been noted but the duration of the positive pressure wave is such that most of the structures failed before suction began. A British report estimated that normal dwellings such as are common in England would collapse at 1,000 yards, become beyond repair at 1 mile and suffer some damage up to 2½ miles. Some glass would shatter at 12 miles. The following features of blast damage were noted in Japan.

(1) At 200 yards, flat, concrete roof slabs 7 inches thick were dished by the downward thrust of the blast.

(2) Very heavy construction concrete buildings were safe from partial collapse but not safe from structural damage within one-half mile.

(3) Light single story concrete buildings failed at one-half mile from the center of the damage.

(4) Steel framed single-story sheds were damaged by mass distortion away from the explosion up to three-fourths of a mile with steel stanchions and roof trusses collapsed. The structural framework of these sheds was damaged up to 1¼ miles. A point of interest is the fact that the pliable covering of these sheds transmitted pressure to the framework with more damage resulting than did coverings which shatter, such as asbestos cement, which absorbed some of the energy in failing and thus gave more blast protection to the framework.

(*b*) Thermal energy and the ball of fire from an air burst are of extremely short duration. However, at 400 yards from the center of the damage, the temperature was well over 1,100° F. Fire damage in Japan was divided into two categories: direct-heat damage and secondary fires.

MATERIAL DAMAGE BY FIRE

AIR BURST SIMILAR TO HIROSHIMA AND NAGASAKI

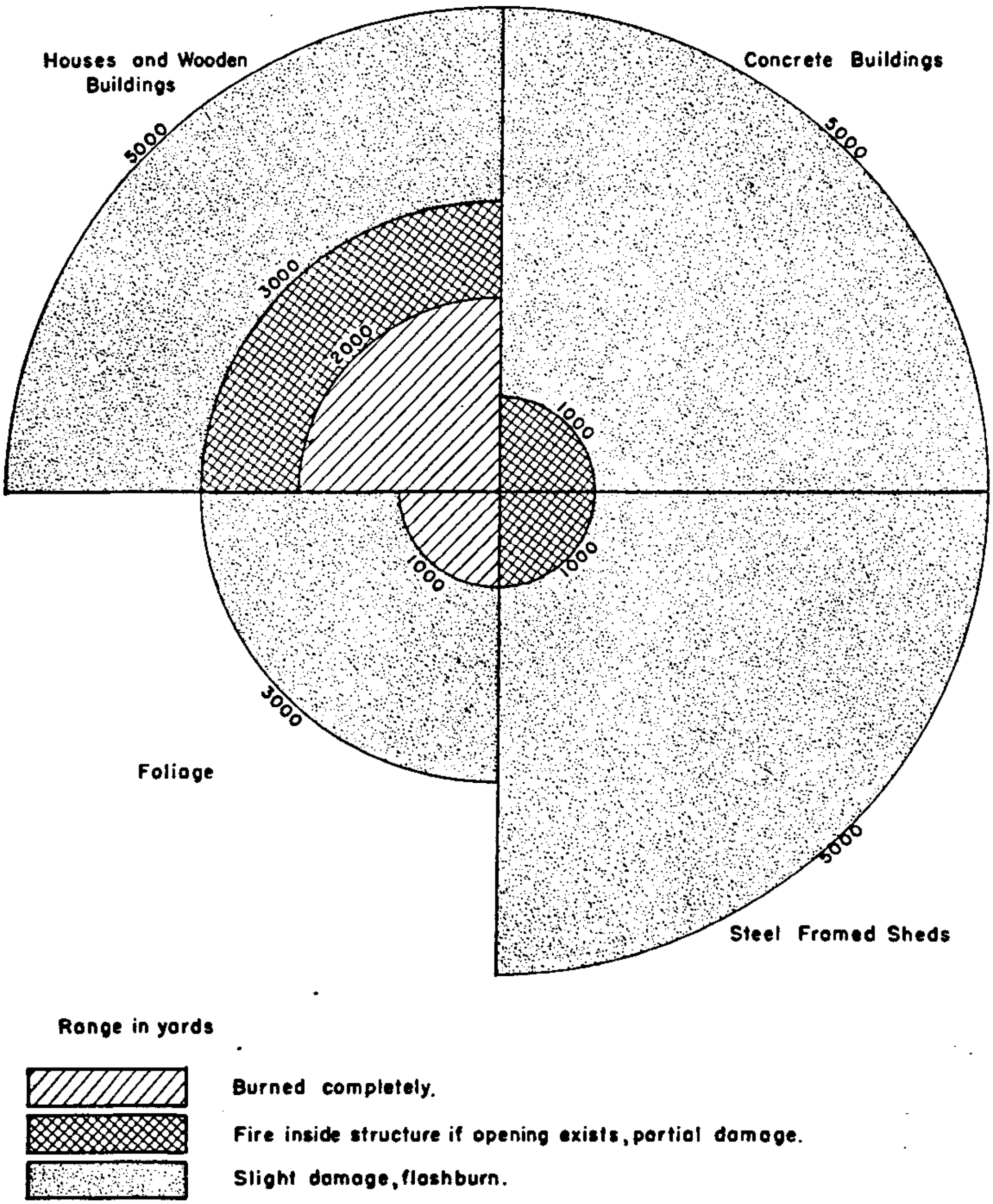


Figure 5.

(1) Direct-heat damage from the explosion, from the ball of fire and from thermal radiation is believed to have accounted for 60 percent of all fire damage in Nagasaki. Surveys showed that vegitation was burned completely at 1,000 yards with some fired at greater distances. Unscreened buildings at 1 mile were subject to fire from direct radiation. Trees at 3,000 yards showed flash-burn marks and some materials ignited at this distance.

(2) Secondary fires originate from overturned stoves and furnaces, broken power lines or spreading of other fires.

240. Consequences peculiar to an underwater detonation.

241. An underwater detonation (plate II) first becomes visible with the appearance of a relatively small (50 to 500 yard diameter) white spray dome followed by a dull red flash. This dome expands and rises. A surface shimmer of about 800 yard radius, caused by the shock, appears. A column of water is forced up to a height of about 2,000 feet. This column has an inverted cone shape, is 450 plus yards in diameter at the base and is estimated to contain several hundred thousand tons of water. As the shock wave spreads, the air behind it expands causing condensation and giving the effect of a huge vapor dome. A mushroom shaped cloud, made up of mist, steam, smoke, fission products, and unfissioned particles, rises and spreads to a great diameter. The sea waves propogated from the center of the burst are about 30 feet high at a distance of 1,000 yards with 500 yards from crest to crest. At 5,000 yards they are about 6 feet high. A dense spray, caused by base surge and falling water is formed at the bottom of the column. This heavily contaminated mist rolls out covering an area of several square miles and turns into a heavy fog. Finally, a downpour of rain begins, its origin being the base spray, fog, and the moisture in the cloud. At Bikini it covered an elliptical area of over 5 square miles with the longer axis being the result of a light breeze. This combination of rain, mist and fog carries contaminating agents which initially give off radiation intensities in thousands of roentgens. The water below it becomes contaminated on the surface, the radioactive agents diffusing vertically at the rate of about 10 feet in 5 minutes. All effects of a subsurface detonation, as in air detonations, are subject to variations as bomb size and depth of detonation vary. The succeeding paragraphs explain the effects which manifest themselves as hazards to personnel and to operability as a result of an underwater detonation.

242. Damage to personnel vs. range.

(*a*) The actual blast hazard to personnel extends to about 600 yards, although shock injuries will extend to one-half mile. Personnel low in the ship are especially susceptible to secondary shock injuries, and it is estimated that about 25 percent of lower-deck personnel will be casualties at 600 yards. This figure falls for persons on higher-deck levels (from secondary shock effect only).

(*b*) The high waves will sweep over the deck washing people and loose gear over the side. On large ships this hazard exists up to 600 yards, whereas landing craft and other small ships will be subject to this hazard as well as to capsizing as far out as 1,000 yards from the center of the burst. The original waves caused by the burst carry few radioactive agents.

(*c*) Water is an effective shielding device against thermal radiations, neutrons and gamma rays given off at the instant of burst. Several feet of water stops the most penetrating neutrons emitted.

(*d*) Contamination is the greatest hazard to personnel. All men exposed directly to the contaminating rain, spray or water may get lethal doses of radioactivity. The effects may not become evident, however, for a period of at least 24 hours (pars. 153–154). The water within neutron range of the detonation will become contaminated through high intensity induced radioactivity in the sodium as well as from the fission products and the unfissioned parts of the bomb it will hold. This volume of water will diffuse horizontally contaminating surrounding water. The range of contamination will depend somewhat on wind and current. Personnel protected from direct contact with this contamination but not well shielded from that which lodges on the ship are likely to receive a fatal dose of radiation within a variable period of time if decontamination is not effected or the men evacuated. Openings in the ship, such as hatches, ventilation ducts or sea suction chests, will be a means of entry for contamination, allowing the hazard to extend well inside the ship and adding to the effects of gamma rays which penetrate from contaminated weather surfaces. Prompt maneuvering may aid materially in getting the ship beyond the areas of heavy contamination in the water, mist and rain. Contamination of personnel may be lessened a great deal by prompt donning of gas masks.

243. Ship damage from an underwater burst.

(*a*) Blast causes four distinct effects which, with their combinations, will damage ships within several hundred yards. These four effects are: the subsurface shock pulse, sea waves, air blast waves and secondary shock. The shock pulse is transmitted through the water and is capable of sinking ships within 500 yards. Its effectiveness diminishes rapidly with distance beyond this range.

The strength of the blast pulse, transmitted through the atmosphere, varies with the depth of the detonation. Its effect is considered along with the high sea waves also propagated. The combination of the two will cause considerable topside damage to ships within a few hundred yards.

The secondary shock pulse transmitted throughout the ship is capable of displacing machinery and other objects which have high inertia or are mounted on flimsy supports.

(*b*) The operability of ships is greatly affected by contamination, as discussed in paragraph 242.

244. Shore damage from a harbor detonation.

(*a*) There is no precedent of a harbor detonation from which to derive information. In visualizing such an attack, results can only be estimated in general terms because of the numerous variables involved. The principal causes of variations are depth of the harbor, distance the detonation is from the shore, the contours of the surrounding terrain, depth of the detonation and the physical arrangement of the structures in the harbor area. The hazards resulting from a harbor detonation will be similar to those in any subsurface detonation and the consequences will differ only because of the above variables and the type of material within effective radius.

(*b*) The shock pulse will collapse docks and other structures built out in the harbor and will sink ships in the harbor if the burst is within several hundred yards. Air blast and sea waves will wreck structures on the shore if they are within a certain range.

(*c*) Ships, land, water, and land structures within the contamination pattern will receive radioactive agents, denying or restricting the use of the entire pattern area until decontamination can be effected. Most harbors contain floating debris and oil slicks which are effective holders of radioactive particles and this hazard must be taken into account before the area is declared safe.

(*d*) The contamination in the water must pass out through the harbor entrance or lose its radioactivity very slowly through the settling of fission products and unfissioned particles to the bottom or through natural decay before the harbor is again completely safe for operation. The change of water will be rapid in the case of harbors into which large rivers flow or those which are only partly enclosed, whereas harbors with small entrances and little source of new water may hold contamination for weeks or years. The bottom will, in any case, hold contamination for a considerable period, rendering operations involving divers hazardous and only advisable if undertaken under the supervision of Radiological Safety personnel.

CHAPTER III

300. Detection: Instruments, Facilities and Procedures.

310. Measuring devices which indicate the presence and amount of radioactivity in an area are divided into those which provide a reading of the intensity and those which register accumulated radiation over a period of time. In lack of the latter type, the instantaneous reading instrument may be used with a watch in lieu thereof, providing intensity is constant. Similarly the accumulative type can be used with a stop watch to determine instantaneous or rate of radiation if kept in an area of constant intensity during the short period observed.

311. Detection instruments that give readings of radiation intensity are of three types: Ion Chambers, Proportional Counters, and Geiger Counters. These types vary principally in their voltage ranges (fig. 6) but also have other differences. The voltages expressed in figure 6 are typical of those employed in early instruments. The services are not yet firm on the exact characteristics of instruments to be used in the field. Because of changes in geometry and in the gas filler, counters finally accepted will probably vary from the voltage ranges herein used for exemplification.

(a) The Ion Chamber is a "rate" meter consisting of an enclosed volume in which ionization is produced by radiation passing through it and which has a means for collecting the charge resulting from such production of ion pairs. (As previously stated, ionization is that process in which a particle of molecular size or smaller, ordinarily electrically neutral, acquires an electrical charge in the production of an ion pair.) One electrostatic unit of charge is 2×10^9 (2 followed by nine zeros) ion pairs. And since the amount of X-ray or gamma ray energy which creates 2×10^9 ion pairs is equal to one roentgen unit, the ionization taking place in an ion chamber can thus be calibrated in roentgens per unit time (r/day). There is no ion amplification in Ion Chambers because the low voltage used does not give the ions sufficient velocity to cause further ionization. The voltage range is below 500 volts (fig. 6). At low voltages, a geiger tube may be used as an ion chamber.

(1) At present, the most common adaptation of the ion chamber for field purposes is the Victoreen 247 Survey Meter. This is an instrument about 1 cubic foot in size and between 17 and 20 pounds in weight. The chambers and associated circuits are in moisture-proof containers. The 247 has 3 scales covering the range of 0 to 200 r/day and records gamma radiation only. Because of its range, the ionization type instrument is used when high levels of radiation are encountered.

(2) General characteristics of ionization chambers are:

(i) Sensitivity, at least in portable instruments, is inferior to that of the portable Geiger counters so that the ion chamber is not a good instrument for obtaining very low readings.

(ii) Insulation of the highest quality must be maintained in the chamber circuit. Therefore, careful stowage and handling to insure adequate shielding from moisture and contamination is required.

(iii) Considerable D. C. amplification is required in the amplifying circuits and the amplifier may be unstable or may change sensitivity.

(iv) Current drain of the D. C. amplifier requires large batteries thus resulting in cumbersome weight.

(v) Very thin windows may be used in laboratory instruments, permitting the detection of alpha particles. Up to the present, it has been found impracticable to measure alpha with the 247.

(vi) A wide band of intensity may be covered by one instrument.

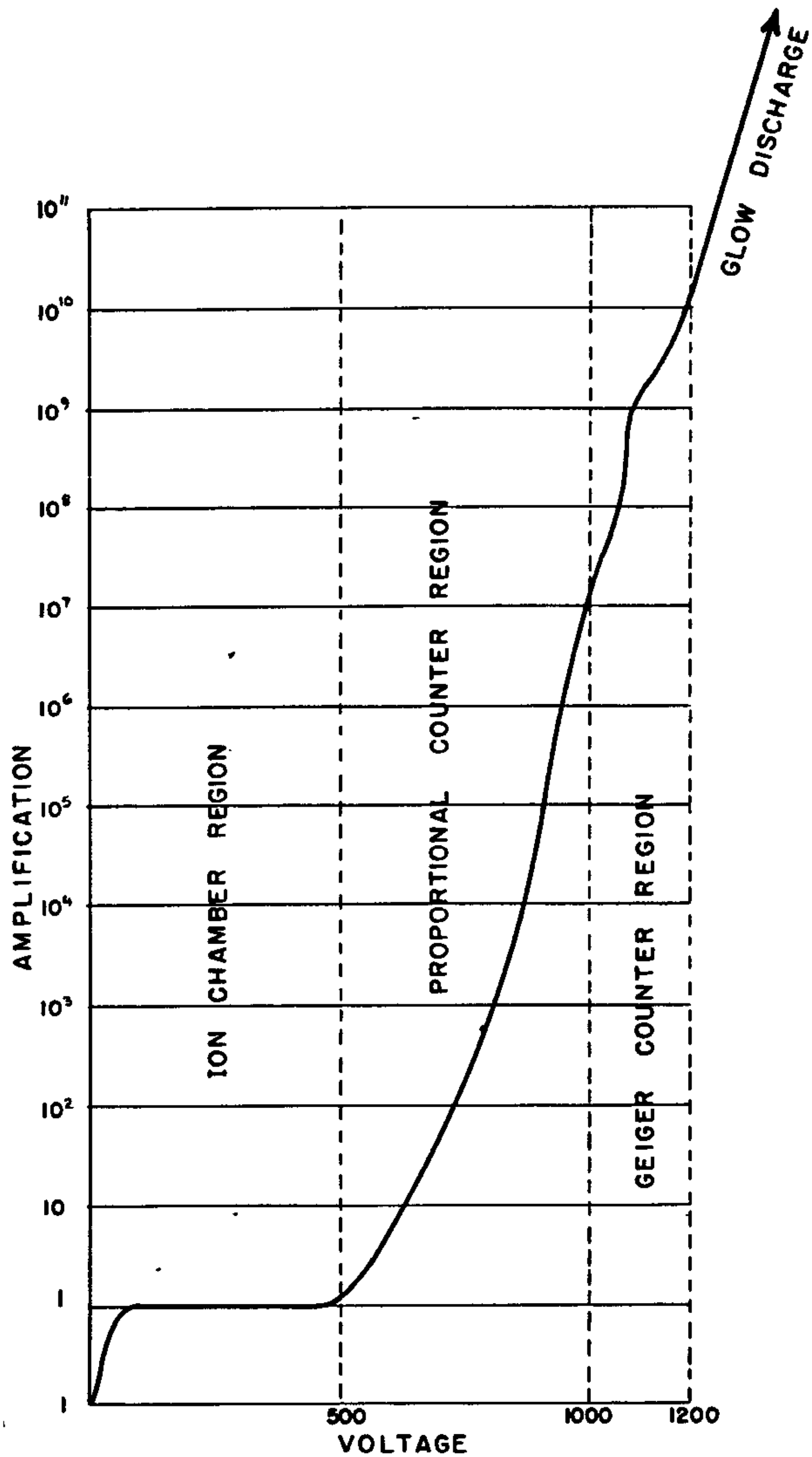

GLOW DISCHARGE
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10
1
1
AMPLIFICATION
ION CHAMBER REGION
PROPORTIONAL COUNTER REGION
GEIGER COUNTER REGION
500
1000
1200
VOLTAGE

Figure 6

(*b*) The Proportional Counter is a Geiger tube in which ion pairs are multiplied by an amplification feature due to the fact that a voltage range of 500 to 1,000 volts is used, thus giving the ions velocity sufficient to cause further ionization. This amplification takes place in rarified gas and has been given the name of "gas amplification." This increased pulse intensity is effected in order to obtain greater sensitivity and thereby detect lower intensities. Ionization is amplified as high as 10 million times. Proportional Counters, although usable in the field, are more extensively used in laboratories.

(1) The common application of the Proportional Counter uses an electronic scaling device and measures alpha disintegrations. The scaling device consists of a mechanical counter attached to a Geiger tube through a suitable electronic circuit. The mechanical scaler registers a certain fraction of the pulses. The most common scaling circuits are calibrated so that they must be multiplied by 32 or 64 to obtain the actual count.

(2) General characteristics of proportional counters are:

(i) Primarily a laboratory instrument in its present state of development.

(ii) High sensitivity and wide range. This instrument registers separate disintegrations. It can resolve disintegrations received at rates from 1 to 50,000 disintegrations per minute.

(iii) It requires a high voltage, but includes a means for adjusting applied voltage.

(iv) Voltage must be adjusted as a calibration prior to and during each use.

(v) Readings are in counts or disintegrations rather than intensity or dosage as in the rate meter (Ion Chamber or Geiger Counter).

(*c*) The Geiger Counter principle in instruments issued to the fleet will be as a "rate" meter consisting of a suitable electronic circuit and a Geiger tube. This tube is a simple gas-filled thin-walled tube lined inside with a metallic cylinder to serve as one electrode and a fine tungsten wire axially mounted in the center of the tube acting as the other electrode. Since the Geiger Counter is operated in the voltage range of 1,000 to 1,200 volts (fig. 6), the ions produced in the tube are amplified as high as 10 billion times. This high amplification gives very high sensitivity and enables the detection of intensities as low as 0.002 r/day. However, since it has such high sensitivity, it has a very low range. The Geiger counter detects gamma and beta-gamma radiation.

(1) A common adaptation of the Geiger Counter for field purposes at present is the Victoreen model X–263 (plate III). This is a small (about 250 cubic inches) and light (between two and four pounds) instrument encasing its own portable batteries. Earphones are provided for audible detection of the pulses in addition to a meter for scale readings. The X–263 records readings in milliroentgens per hour (mr/hr) and must be converted by the operator. Present types have a range from about 0.01 mr/hr to 20 mr/hr (0.002 r/day to 0.48 r/day) and are therefore used for surveying lower levels of gamma and beta-gamma radiation.

(2) General characteristics of Geiger Counters are:

(i) High sensitivity and low range.

(ii) While extremely good insulation is not required, there is a relatively high voltage on the Geiger tube and the leakage problem may be serious.

(iii) Because of the higher gas amplification, more simple electronic circuits are used in portable meters of this type.

(iv) Exact voltage on the Geiger tube is vitally important and correct readjustment of voltage is not easily attained.

(v) At high radiation intensities, counts may be lost, or meter may become "paralysed." For example, if the upper limit of the X–263's range of 0.48 r/day is exceeded, the meter will swing off off scale and audible sound will change from clicks either to a steady buzz or the meter will become "paralysed" and no sound will be heard.

(*d*) Special applications of instantaneous measuring devices:

(1) *Deep Water Probe.*—A Geiger tube is attached to a waterproof cable and lowered to various depths. A meter registers the readings topside and the length of cable reeled out determines the depth at which the reading was taken.

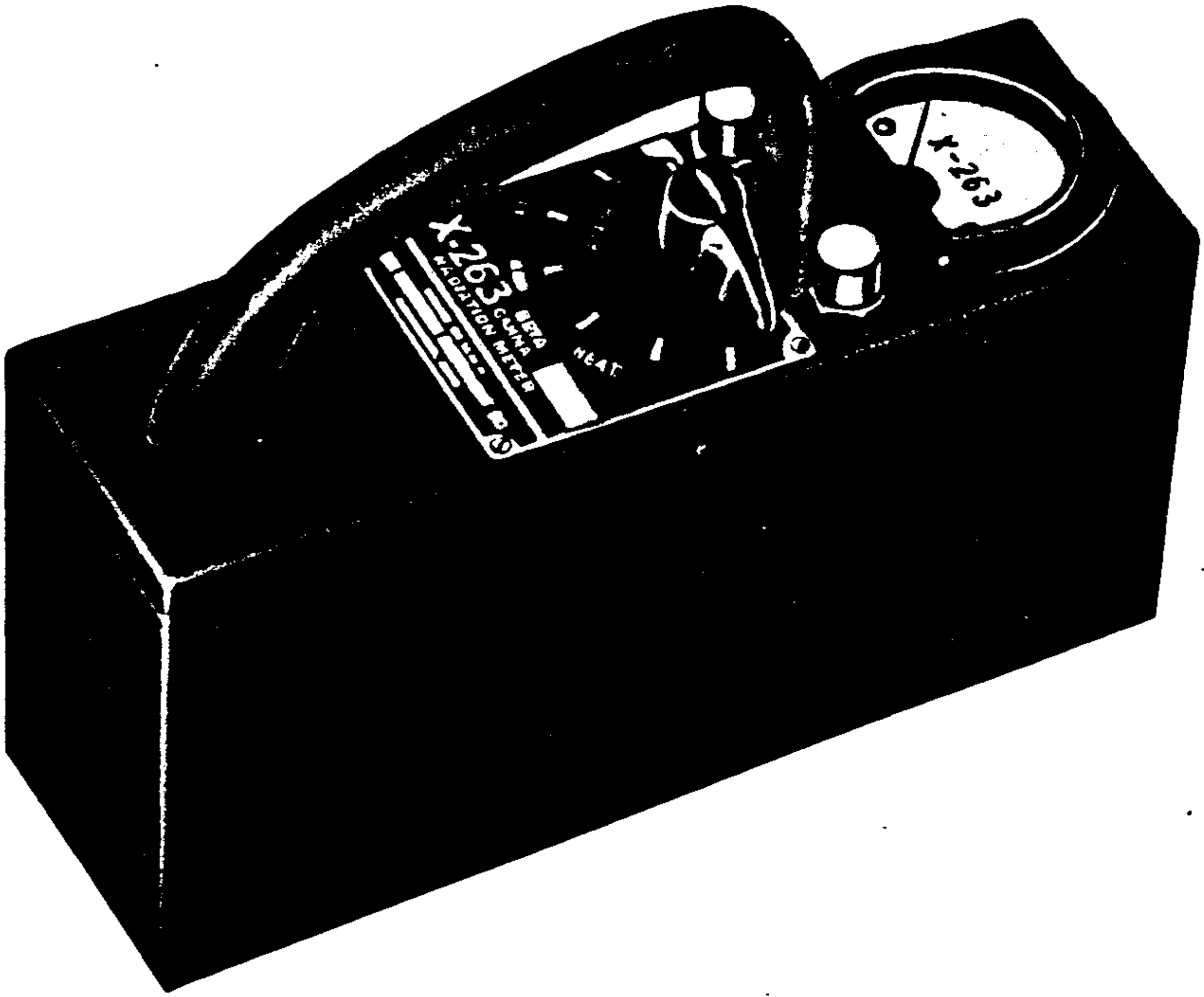


Plate III. Typical Geiger tube survey meter with integral battery supply (X–263).

(2) *Water Sampler.*—A Geiger tube is located inside a pipe and samples of fluid are passed around the Geiger tube constantly. An indicator is located outside of the pipe which registers the amount of radiation in the fluid samples tested.

(3) *Sonobuoy Geiger Meter.*—Geiger tube connected to Sonobuoy, pulses of which key a radio transmitter. The radio pulses are picked up by a remote telemeter and recorded.

(4) *Telemeter.*—Remote meter connected to a radio receiver which registers readings sent to it by radio from a source at some distance from the telemeter.

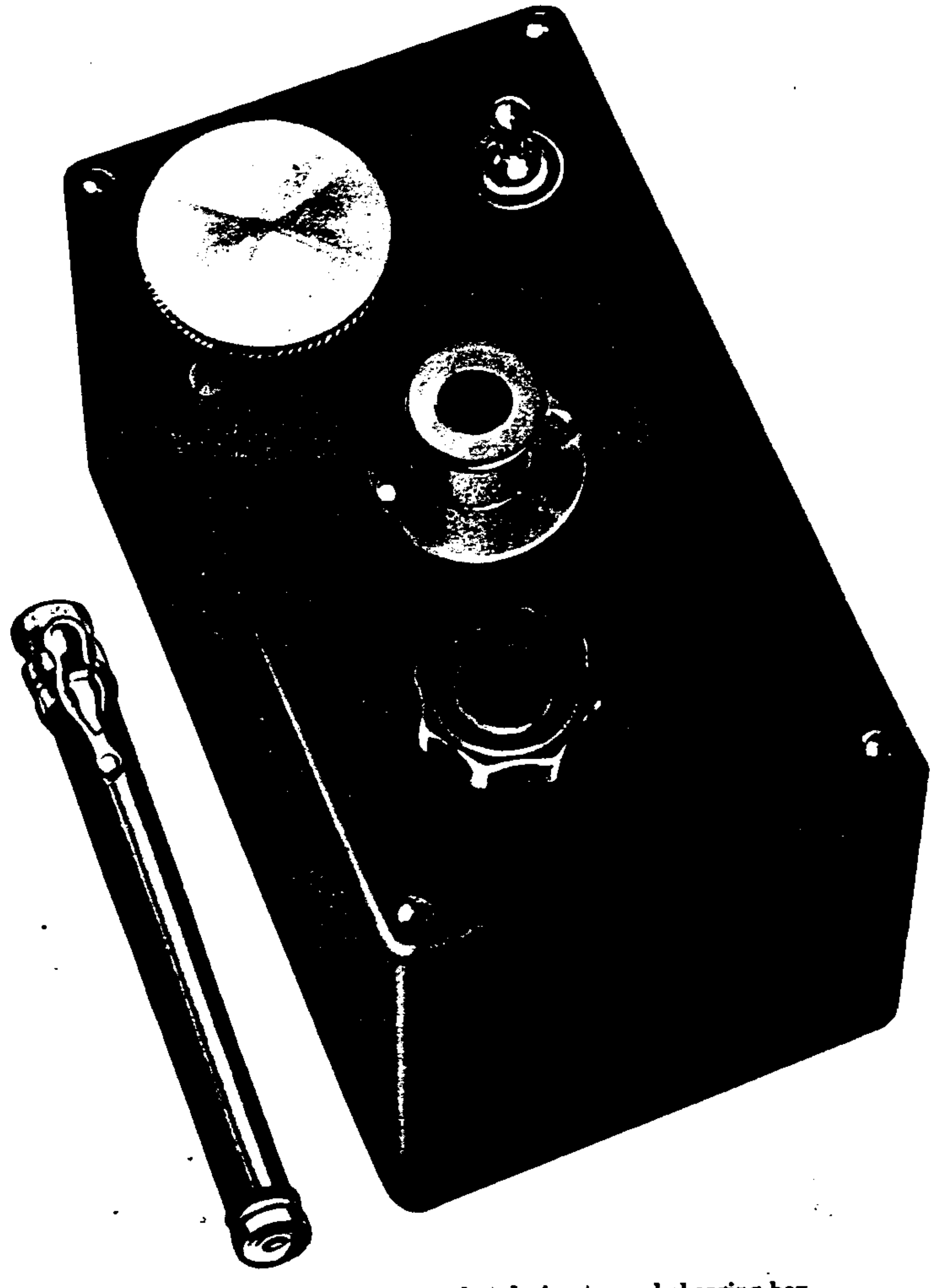
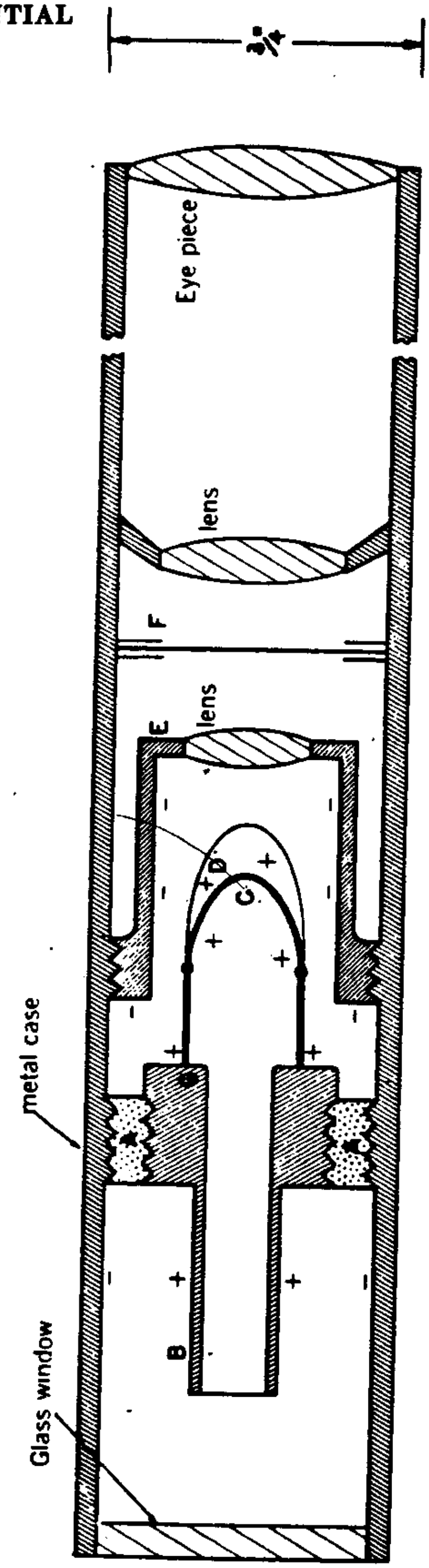
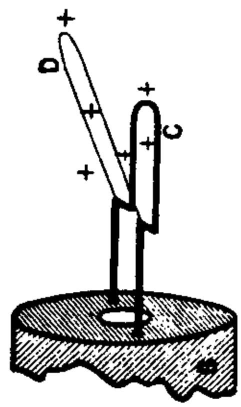


Plate IV. Electroscope type (L-W) pocket dosimeter and charging box.



A · Insulating ring
B · Charging rod (hollow to admit light from window)
C · Fixed heavy metal coated quartz fiber
D · Movable fine metal coated quartz fiber
E · Metal cylinder
F · Transparent scale
G · Metal support for fibers



Side view showing arrangement of fixed and movable fibers

Figure 7. Pocket dosimeter electroscope.

312. Detection devices that give accumulative or integrated readings of radiation have been arbitrarily divided into three types: Electroscopes, Electrometers and those involving photochemical reactions. These types vary greatly in their design but they all record the total dosage received over a period of time.

(*a*) The Electroscope contains a charged metal foil or fiber which becomes neutralized when ions are formed inside the case by radiation. The amount of radiation received by the instrument is proportional to the amount of neutralization of charge. This instrument utilizes the principle of electricity wherein like charges repel each other. The ionization within the chamber neutralizes these charges so that the metal foil or fiber returns to its uncharged position. The electroscope does not require continuous external voltage for operation but when discharged must be recharged from an external source.

(1) The Lauritsen Electroscope is one conception of this type of instrument.

(2) The Pocket Dosimeter is the application of the electroscope that is most important in field usage. Instruments of this type can be made sufficiently rugged to withstand the shock of normal human activity, are small enough to be worn comfortably, and are very useful for measuring integrated exposures. The instrument is about the size of a large fountain pen (fig. 7). The conducting system in the dosimeter consists of two quartz fibers each bent into a U (*C* and *D* in illustration). The two fibers are fused together at the ends of the U and a microscope is focused at the end of one fiber (*D* in illustration). Contained within the microscope is a transparent scale so that the movement of the movable fiber gives direct readings of radiation received. A charge placed on the fiber system causes the fibers to diverge by mutual repulsion and ionization within the chamber will neutralize this charge. The protective cap on the end of the dosimeter has a small window for illumination of the fiber and scale. When the cap is removed, a contact is exposed for charging the fiber system from an external battery.

(*b*) The Electrometer is essentially a laboratory instrument that is particularly suitable for measuring low-energy beta rays. In this instrument, a metalized quartz fiber is held under spring tension between two charged plates which are connected to a 100 to 200 volt battery contained in the instrument. The position of the fiber depends on its own charge, since any charge will be repelled from one plate and attracted to the other. The central fiber is connected to an ion chamber which collects the ions produced by radiation. Thus, the movement of the fiber determines the radiation received by the instrument over a period of time.

(1) Wulf String Electrometer is essentially a laboratory instrument and the field use adaptation of it is the Proteximeter.

(2) The Proteximeter is an instrument using an electrometer tube to measure the charge collected in an ionization chamber. It is a small instrument which records the accumulative dose of radiation to which it is exposed. It covers a greater range than the pocket dosimeter and contains its own portable batteries for producing an electric field between the collecting electrodes.

(*c*) Photographic Dosimetry is the use of photographic film to determine the amount of radiation received over a period of time. Upon exposure to radioactivity, the silver salt contained in the photographic film is converted to developable metallic silver. Upon developing the film, the opacity caused by this deposit indicates the amount of radiation received. Usually the film is the size of small dental X-ray film (1½″ by 1¼″) with a lead foil cross wrapped around it so that only the corners of the film are exposed (fig. 8). Most gamma rays will pass completely through the uncovered portion of the film so this uncovered portion will record beta readings. The lead foil excludes the beta radiation so that only gamma exposure is recorded under the foil. The film badge is worn by everyone working in or near radioactive areas and upon developing of the film, gives a reading of exposure received by personnel.

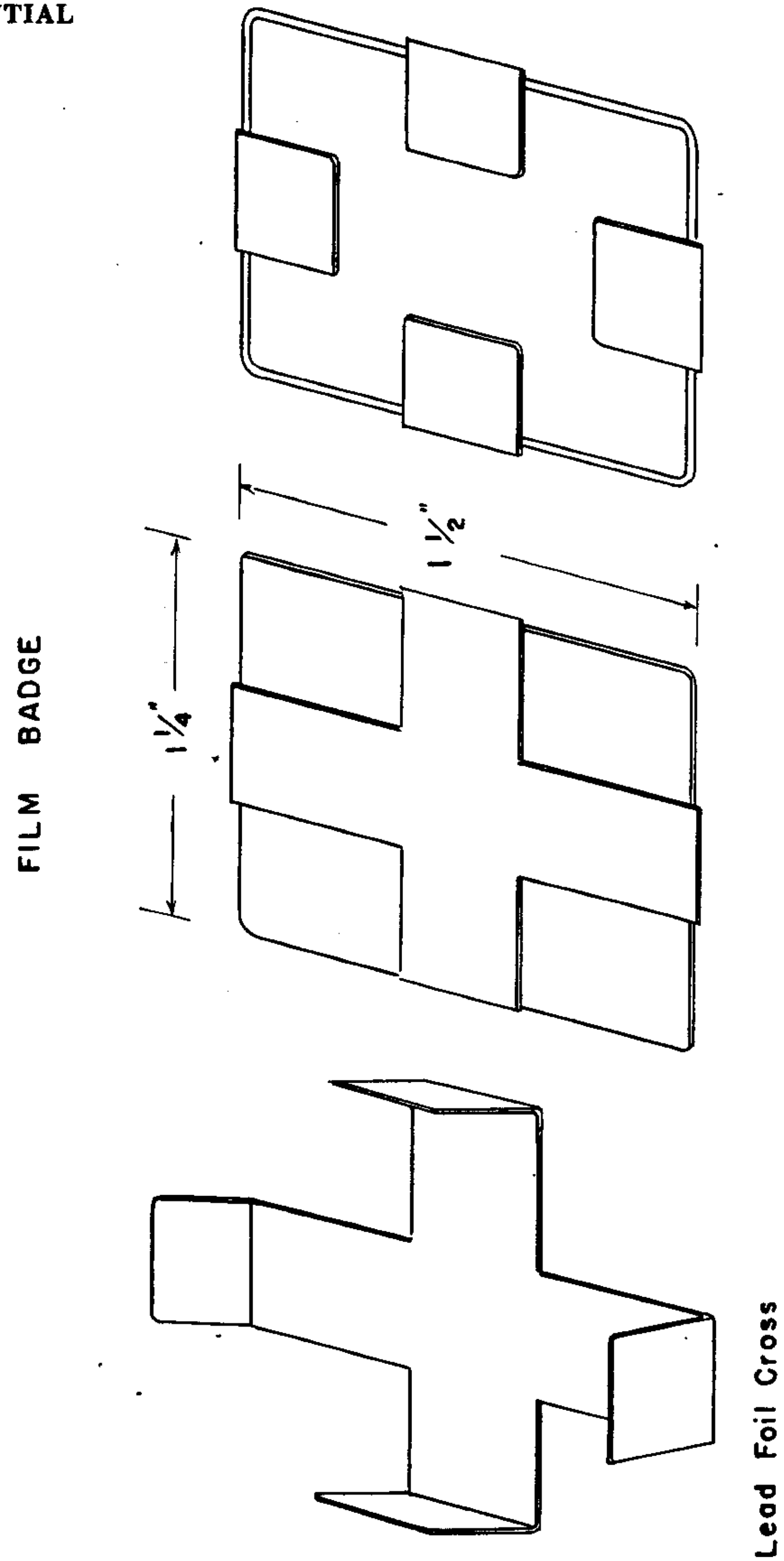


Figure 8.

313. Instrument Development Projects.

(*a*) There are new requirements in instruments which are being incorporated by BuShips in new specifications. It is expected that these will result in:

(1) Improved portable, high sensitivity, beta-gamma survey meter.

(2) Portable alpha survey meter.

(3) Portable, low sensitivity, high-range beta-gamma survey meter.

(4) Portable, high sensitivity, directional, beta-gamma survey meter.

(5) Fixed or mobile installations for detection of all degrees of concentration of beta and gamma radiation with local readings, plus telemetering equipment for remote indication.

(6) Portable dosimeter, pocket type, with higher ranges than present types.

(7) Improved film badges, direct indicating, if possible, covering alpha, beta and gamma radiation.

320. Supplementary Equipment and Facilities.

321. Standard electronics calibration and repair equipment.

(*a*) The luminous buttons placed aboard nearly every vessel of the fleet contain 10 micrograms of radium per button and these can be used to calibrate the various instruments used in Radiological Safety work since they give off 2.0 r/day at one centimeter range in air. It is expected, however, that eventually calibrated sources of radiation will be supplied to each ship or station for use in calibration of instruments.

(*b*) The circuits used in the various Geiger counters and ion chamber units are elementary and any ETM will find them easy to check, repair, and keep in condition if he has sufficient spares. It will only be necessary, that he be taught the additional principle of the Geiger tube.

322. Stowage.

(*a*) A dry place well within the interior of the ship (such as the gas-mask stowages) must be found for the instruments. These stowages must be well padded so that instruments are not jarred or broken. A routine check should be made weekly to see that batteries show proper voltage, that instruments record properly and that the space is clean and free of dust. The reason these instruments must be located well within the interior of the ship is so that they will be afforded maximum shielding from initial radiation in case of an atomic attack. The continual exposure of one or more accumulative instruments for the purpose of determining the amount of radiation sustained prior to intentional use and as a warning measure may at first seem advisable. However, the following factors eliminate the use of existing instruments for this purpose:

(1) The life of the batteries contained in the proteximeter prevent such use for any length of time.

(2) Film badges deteriorate with time and under unfavorable temperature and humidity conditions.

(3) Dosimeters have the fault of natural leakage of charge over short periods but would be acceptable except for their low range.

(*b*) Undoubtedly the developments mentioned in paragraph 313 above will eventually include such a warning and initial dosage reading instruments, thus permitting proper stowage and shielding of all other instruments.

323. Equipment required for photographic dosimetry.

(*a*) Dark room capable of accurate and constant control of temperature of room and of water used in developing film.

(*b*) An accounting system must be kept for the filing of records of film badges. All film badges must be numbered and an accurate check must be kept to determine who has used each film. This file should contain the records of film processed plus a record of composite dosage received by each person.

(c) A densitometer, calibration scale and calibration chart.

(1) On larger ships, a densitometer and calibration scale will be available for photoelectric comparison of opacity (darkness) of film exposure. The densitometer is an instrument using a photoelectric cell to determine the degree of darkness and the calibration scale converts this reading into roentgens.

(2) For smaller ships, photographic dosimetry facilities will be furnished as much as possible by bases, tenders or large combatant ships. However, a calibration chart will be available for such small ships. This is a strip film developed to various degrees of darkness and each frame is calibrated as to the amount of radiation capable of producing such exposure. By visual comparison of exposed film with the calibration chart, a fairly accurate estimate may be made of the exposure the film has received.

324. Additional monitoring equipment.

(a) "Filter Queen"—modified vacuum cleaner used on ventilators and deck to pick-up and pass dust and air through a filter which in turn is checked for radiation intensity by the various instruments.

325. Laboratory functions.

Laboratories located ashore or on hospital or other large ships and equipped with instruments, more sensitive and more reliable than those used in the field, will be of value in calibrating the latter or for checking samples so used in calibration.

326. Centralized Control Station.

The exercising of centralized control is a command function. The station selected as the central control station after an atomic attack should be one affording communication and plotting facilities. Normally, for a task group at sea, if undamaged, uncontaminated and not completely engaged in more urgent tactical use, it will be the regular station of the O. T. C. with its CIC. For a naval base, a similar station will be necessary. For a vessel it will be the normal Damage Control Central unless damage or contamination demands use of a secondary or an improvised station. In any case, the OTC or Commanding Officer should have the best available RadSafe advice (including medical and aerological) at this station. As reports are received from monitors, they will be evaluated and the necessary action prescribed.

327. Change Station.

This will be an uncontaminated compartment, building, ship or area with two entrances, one labelled "contaminated" and the other "uncontaminated." A shower or washroom will be located between these entrances, if only a makeshift one. Monitoring and laundering facilities will be available in conjunction with this station.

330. Procedures.

Applicable to most problems of detection are procedures for estimating intensities that cannot be reached by instruments or probes without endangering personnel.

(a) Upon first reaching a point of tolerance radioactivity, circling tactics are best for determining the limits of the radioactive area. Although shielding may blanket some sections or sectors, it should be continuously borne in mind that radiation is three-dimensional and *distance is the best protection*.

(b) A rough rule for computing the intensity near a point source through air is the Inverse Square Law. This law states that intensity of radiation varies inversely with the square of the distance in air. For example, if in circling a source of radiation, a monitor obtains a reading of 0.1 r/day around a circumference which has a radius of 9 feet, he may assume an intensity 1-foot from the center of 8.1 r/day. Obviously, this rule has its fallacies in that the medium through which the radiation passes may not consist entirely of air nor will the source be a point source. It therefore must be applied with good judgment.

(*c*) Intensity may be estimated by extrapolation. This procedure involves passing the source at two, or better, several different distances and plotting a curve which may then be extended for points within the closest range. In this case, as well as in the application of the inverse square law, shielding mediums should be taken into consideration.

(*d*) In all detection procedures, the safety regulations of paragraph 422 apply.

331. Personnel Monitoring.

(*a*) Whenever personnel have been exposed to radiation by atomic attack or by subsequent sorties into a contaminated area for rescue, detection or decontamination purposes, their person and clothing will probably be contaminated. The determination of the existence and degree of this contamination will be established at once by personnel monitoring, which will be conducted at the Change Station. Personnel evacuating the contaminated area will enter the Change Station through the "contaminated" entrance and the Radiological Safety Officer or one of his assistants will monitor clothing, shoes, gloves, skin, and hair of each individual. Pocket dosimeters and film badges will be checked at this time. Personnel decontamination measures (sec. 420) will then be taken as indicated by the radiation readings thus obtained. After showering a second monitoring check will be made. Departure from the Change Station then will be made through the "uncontaminated" entrance.

(*b*) Personnel will carry pocket dosimeters and film badges while working in contaminated areas. These will be checked at the end of work and readings recorded on individual reports of each person. Should an entire vessel or station be subjected to radiation hazards or become engaged in rescue or salvage operations assisting a contaminated vessel or station, the accounting system is likely to reach vast proportions. Only full understanding and cooperation by all hands involved can keep the necessary clerical work within reasonable limits. Although dosage received is a medical department responsibility, it is conceivable that flexibility of organization will be needed to provide additional clerical assistance.

(*c*) Further check of evidence of radiation will be made by urinalysis, nasal swipes, blood counts and bone marrow samples as BuMed may direct.

332. Ship Monitoring presents a problem very similar to others in damage control. Time is the important factor and the Commanding Officer, after an atomic detonation, will require all information so that he can quickly arrive at sound decisions. Monitoring of the ship will entail, therefore, two steps: first, an initial or preliminary inspection and following this, a detailed inspection.

(*a*) The preliminary inspection will be conducted with two aims in view. The Radiological Safety Officer will want to know the location and intensity of radiation hazards and refuge areas of low intensity so that personnel can be protected by distributing them within the latter. To accomplish this, the repair parties should have a definite route of travel decided upon prior to the burst. This will allow a maximum area to be inspected in the minimum of time. These parties should be furnished with a rough plan of the ship (or parts of the ship that they are to inspect) so that readings may be recorded directly on this plan and highly radioactive areas marked off to restrict personnel from such areas or if a greater part of the ship is highly radioactive, it may be easier to mark off safe areas. By marking intensities on this rough plan, it is much easier to envisage the areas of high contamination and the consequent limitations imposed. In a case where a ship is necessarily abandoned because of high intensity, the salvage of the ship by another vessel or group will be simplified by this data.

(1) Care must be taken in the use of the various instruments so that they do not become contaminated with use. The instruments, in checking radioactivity, should be held as close to the surface to be measured as possible, yet not touching the surface. If the instrument becomes contaminated itself, the readings will be false.

(2) There are certain areas and material on a ship that will be especially subject to radioactivity. These should be carefully checked. They are cordage and canvas, rough and rusted surfaces, greasy and oily surfaces, bituminous coverings, low places, pumps, drains, scuppers, and any wood.

(*b*) Following the preliminary inspection and at regular intervals as decontamination proceeds, a detailed inspection of the ship should be made by the Radiological Safety Officer and his assistants. This inspection is made to obtain more knowledge concerning the location and intensity of contamination in order to further protect personnel and to give the information needed for decontamination parties. For this inspection, it will be found that BuMed–BuShips Form #1 (p. 3–17) will be very helpful as a guide in obtaining the information needed.

333. Sea Monitoring is a new item in ship tactics evoked by the advent of atomic warfare. The existence of radiological hazard at sea (or in a harbor) will require the determination of exact locations and intensities which, with probable movement resulting from wind and current, will influence the course of action. This type of monitoring involves the survey of any water surface and below the surface to ascertain the area or areas completely denied to our own forces and those into which intermittent or full access is possible for salvage, rescue or other operations.

(*a*) Although the use of drone planes and boats with adequate instrumentation installed would be ideal for the preliminary survey of a contaminated area, their existence in a ready condition is improbable. Consequently full dependence should be placed upon personnel operated planes and boats. As stated under air monitoring, preliminary reconnaissance by planes may roughly establish water areas of high intensity by extrapolation. Low freeboard vessels or boats carrying counters are most desirable for survey of water areas. Larger ships, by using detection devices on sea intakes, by lowering counters from decks or by extrapolation of readings because of freeboard can be used but the desirable feature of maneuverability would be lacking. The instruments described under paragraph 311 (*d*) may find application in some cases of sea monitoring but normally the standard hand carried detection meters will be used.

(*b*) The procedure to follow will vary with the circumstances particularly the tactical, oceanographical, and aerological situations and the forces and materials available.

(1) Normally the Centralized Control (OTC) will determine the need and nature of the survey to be made and devise an appropriate plan using a direct approach from upwind sectors until contact with the edge of radioactivity is made, at which point, either a tangential or radical zigzag approach will be used to penetrate the area.

(2) The communication plan should provide reliable and immediate exchange of information between centralized control and monitoring parties to permit vectoring and in order that isodose lines may be established and promulgated. Isodose lines are defined as lines of constant intensity. From precedent established at Bikini, the Red Isodose Line is that bounding the area within which no ships or boats can operate. The Blue Isodose Line is that bounding the area within which daily tolerance is exceeded and in which ships and boats can operate only with specific permission and for specified lengths of time.

(3) Operations by monitoring boats should be in pairs unless the depth of water is such that anchoring is possible in case of break-down.

(4) Any oil slicks and debris in or near the area of an atomic burst should be investigated and monitored, as these will pick up and retain radioactive particles so that radioactivity is not dispersed over large areas as with water but rather concentrated in one spot.

334. Land Monitoring following a low altitude, underground or underwater detonation will present some problems not encountered in the monitoring procedures mentioned above. Although there are some advantages in the nature of a shore station such as the lack of the confining features of a ship, possibility of more ready outside assistance and the probability that instruments will have been afforded shielding by dispersed underground stowage, such a command does not present the compact, unified, and controllable features of a ship. For example, liaison with Army and civilian agencies will be required. A naval base will contain all materials found aboard ship plus many found only ashore. Because of the great amount of wood and concrete structures ashore, the porous nature of such material and the probability that it will be highly contaminated, monitoring will be a more extensive problem than aboard ship. In addition, road pavements, earth, docks, machinery, and vehicles will be present and add to detection problems. A further problem is that water used for decontamination of one place merely transfers the contamination to another place which may be equally important.

(*a*) Firefighting, rescue, and salvage personnel must be protected from excessive radiation by the attendance and the advice of a Radiological Safety Officer or his trained assistants. As soon as possible after, or concurrently with, the performance of this duty, an over-all inspection will be necessary to determine roughly all areas of contamination with location and intensity of high radiation sections to which access must be denied or curtailed. The readings gained by this inspection will form a basis for initial isodose lines plotted on a master chart and subsequently corrected as additional information is received.

(*b*) When time is available, a thorough and detailed inspection of the entire area will be made and the preliminary isodose lines carefully checked and corrected. This master chart should be copied as necessary and its information promulgated to all concerned. Decay and decontamination will require remonitoring and changing of the isodose lines.

335. Air Monitoring may be used to determine roughly areas of radioactivity in the air or on the surface.

(*a*) Planes used for cloud tracking with the objective of obtaining data required for avoidance by own air forces or avoidance of possible cloud fall-out by own surface forces will be equipped with airborne Geiger counters. In the early stages (several hours after an atomic burst), visual contact is a possibility but counter readings will be necessary to derive intensities and to identify the cloud sighted with radioactivity. Aerological data should indicate the most probable course of the cloud and the likelihood of cloud fall-out. This data should be consulted in planning the coverage by the monitoring plane or planes in radioactive reconnaissance. The plotting station will maintain constant radar contact and voice communication with each plane, vectoring the latter as intensity readings and ballistic wind or other aerological data requires. Intensity readings and the radar operator's fixes of the plane will be simultaneous. If so directed by the OTC, the plotting station will initiate appropriate warning to own forces. Extrapolation of readings may be desirable in lieu of the monitoring plane actually entering the high intensity areas. The speed of the plane may carry it into some relatively high radiation but in this event, high speed is an asset in that the time of exposure will be correspondingly reduced. Ingestion will be the greatest hazard but it is believed that pressurized masks or cabins will reduce or eliminate this danger.

(*b*) Planes used for preliminary monitoring in connection with a contaminated surface area will be similarly equipped with Geiger counters. Extrapolation for altitude will be necessary. Constant radar plot of and communication with the plane will be maintained by the plotting station. Rough isodose lines of surface intensity can thus be obtained with a consequent reduction in the coverage required of surface monitoring personnel. Also the plotting station will have earlier information upon which to base appropriate warnings for avoidance. Isodose lines thus obtained should be checked by surface monitoring if the situation requires greater accuracy.

BuMed-BuShips Form #1

SHIP .... Location ....

Instrument Type .... Serial .... Date ....

WEATHER DECKS AND TOPSIDE EQUIPMENT

1. Anchor Chain
   Forward port .... gb stbd ....gb
   Aft (if present).......................gb

2. Chain Locker
   Compartment background ....gb
   Chain port .... gb stbd..........gb

3. Topside Line, Fenders, Cable, Bitts and Winches

Object	*Location*	*Reading*
....	....	..........................gb
....	....	..........................gb
....	....	..........................gb
....	....	..........................gb
....	....	..........................gb
....	....	..........................gb

4. Gangway
   Forward port ....gb stbd ....gb
   Aft port ....gb stbd ....gb

5. Small Boats

Hull No. ....
- Maximum keel....................gb
- Maximum rudder ....gb
- Maximum propeller ....gb
- Heat Exchanger ....gb

Hull No. ....
- Maximum keel ....gb
- Maximum rudder ....gb
- Maximum propeller ....gb
- Heat Exchanger ....gb

6. Small Boat Camels and Skids

Location	*Readings*
....	..........................gb
....	..........................gb
....	..........................gb
....	..........................gb
....	..........................gb

7. Deck (Monitor places known to gather contamination and every tenth frame port and starboard).

Location	*Readings*
....	..........................gb
....	..........................gb
....	..........................gb
....	..........................gb
....	..........................gb

....
(Signature of Monitor)

BuMed-BuShips Form #1

SHIP ____________________ Location ____________________

Instrument Type ____________________ Serial ____________________

COMPARTMENT MEASUREMENT

Compartment	*Reading*	*Compartment*	*Reading*
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb

HULL MEASUREMENT

1. Afloat

Location Stbd	*Reading*	*Location Port*	*Reading*
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb

2. In Drydock

Location Stbd at Waterline	*Reading*	*Location Port at Waterline*	*Reading*
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb

3.

Stbd midway between Waterline and Keel	*Reading*	*Port midway between Waterline and Keel*	*Reading*
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb
______	______gb	______	______gb

Location Keel	*Reading*		
______	______gb	Propellers Port	______gb
______	______gb	Stbd	______gb
______	______gb	Rudder	______gb
______	______gb		

Surface of Hull Coated with:	*Percentage*	*Average Reading*
Green growth near waterline	______	______gb
Rust covered areas	______	______gb
Heavy marine growth other than green	______	______gb
Clean hull	______	______gb

____
(Signature of Monitor)

BuMed-BuShips Form #1

SHIP .... Location ....

Instrument Type .... Serial .... Date ....

ENGINEERING SPACES

1. Auxiliary Condenser System
   - Auxiliary injection sea chest (on valve) port ....g
   - Auxiliary injection sea chest (on valve) stbd ....g
   - Auxiliary circulating pump inlet ....g
   - Auxiliary circulating pump outlet ....g
   - #1 Auxiliary condenser salt water inlet ....g
   - #1 Auxiliary condenser header ....g
   - #1 Auxiliary condenser shell, mid-section ....g
   - #1 Auxiliary condenser cooling water outlet ....g
   - #1 Auxiliary condenser outlet elbow (open) ....gb
   - #2 Auxiliary condenser salt water inlet ....g
   - #2 Auxiliary condenser salt water header ....g
   - #2 Auxiliary condenser shell, mid-section ....g
   - #2 Auxiliary condenser salt water cooling water outlet ....g
   - #2 Auxiliary condenser salt water outlet elbow (open) ....gb

2. Cooling Water for Refrigeration System
   - Salt water inlet ....g
   - Salt water outlet ....g
   - #1 Condenser top ....g
   - #1 Condenser bottom ....g
   - #2 Condenser top ....g
   - #2 Condenser bottom ....g
   - #3 Condenser top ....g
   - #3 Condenser bottom ....g
   - #4 Condenser top ....g
   - #4 Condenser bottom ....g

3. Main Condenser ....g
   - Head ....g
   - Shell (near tubes) ....g
   - Cooling water, high injection ....g
   - Main circulating pump ....g

4. Main Engine Cooling System
   - #1 Main lube oil cooler ....g
   - #2 Main lube oil cooler ....g
   - #1 Generator lube oil cooler shell ....g
   - #1 Generator lube oil cooler outlet (open) ....gb
   - #2 Generator lube oil cooler shell ....g
   - #2 Generator lube oil cooler outlet (open) ....gb

5. Emergency Generator
   - Lube oil cooler ....g

....
(Signature of Monitor)

BuMed-BuShips Form #1

SHIP .... Location ....

Instrument Type .... Serial .... Date ....

EVAPORATORS

#1 Unit

First Effect

Shell	............g
Feed heater	............g
Inspection plate on sump	............g
Inside sump	............gb
On evaporator scale	............gb

Second Effect

Shell	............g
Feed heater	............g
Distiller condenser shell	............g
Inspection plate on sump	............g
Inside sump	............gb
On evaporator scale	............gb

Third effect

Shell	............g
Feed heater	............g
Distiller condenser shell	............g
Inspector plate on sump	............g
Inside sump	............gb
On evaporator scale	............gb

#2 Unit (as in #1 Unit)

Salt water circulating line	............g
Condensate cooling condenser	
shell #1	............g
shell #2	............g
Air injection sea suction (at valve)	............g
Overboard, brine	............g
Brine pump strainer	
inboard of	............g
outboard of	............g

FIRE AND FLUSHING SYSTEMS

Main injection	port..............g	stbd..................g
Sea chest	port..............g	stbd..................g
Pump	port..............g	stbd..................g
Overboard discharge	port..............g	stbd..................g
Auxiliary injection	port..............g	stbd..................g
Sea chest	port..............g	stbd..................g
Pump	port..............g	stbd..................g
Overboard discharge	port..............g	stbd..................g

....
(Signature of Monitor)

BuMed-BuShips Form #1

SHIP .... Location ....

Instrument Type .... Serial .... Date ....

FIRE AND FLUSHING SYSTEMS

Heads and Fire Stations

Location	*Indicate g or gb*	*Location*	*Indicate g or gb*
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Mains and Risers

Location	*Indicate g or gb*	*Location*	*Indicate g or gb*
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Sanitary Drainage System

Location	*Indicate g or gb*	*Location*	*Indicate g or gb*
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

Sprinkler System

Location	*Indicate g or gb*	*Location*	*Indicate g or gb*
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

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(Signature of Monitor)

CHAPTER IV

400. Decontamination.

410. General.

411. The objective of decontamination is the freeing of an area from persistant radioactive agents. Inasmuch as there is no practical way to destroy radioactivity, decontamination means the actual removal of radioactive materials which will be in the form of induced radioactive isotopes, fission products and/or unfissioned parts of the fissionable material. At present there are few firm concepts of what the best decontamination procedures should be. BuShips, BuMed and/or the Chief of Naval Operations will release information as it becomes known. It seems probable that considerable emphasis will be placed on the reduction of contamination by design changes and by suitable surface finishes. This chapter outlines principles of decontamination that are currently accepted.

412. Attending an atomic detonation, there are two phases of decontamination which are: (*a*) immediate and (*b*) complete (for practicable purposes).

(*a*) Immediate measures will consist of:

(1) The prevention of the contaminating particles lodging on personnel and structural surfaces or at least reducing this action by

(i) Previously covering structural surfaces with a film of water.

(ii) Gaining a condition of complete closure.

(iii) Warning personnel to take shelter.

(iv) Maneuvering to avoid cloud fall-out and base surge (in case of ships).

(2) The reduction to a minimum of that contamination which is not prevented from lodging by:

(i) Complete bathing, reclothing, monitoring, administering required medical treatment and evacuation of personnel.

(ii) Washing down exposed surfaces to free them of loose contaminating particles.

(iii) Temporarily covering short range emitters with a coating such as paint and which will sufficiently shield against the emissions.

(*b*) Subsequent thorough decontamination may be necessary in order to restore the ship or base to complete radiological safety. Should the survey that follows any possibility of contamination disclose vital areas contaminated beyond tolerance, personnel distribution must be accomplished with their safety the predominant factor but with due regard for the tactical situation. Possibly complete abandonment will be directed with salvage operations falling upon unexposed personnel from another ship or station. Possibly the situation will indicate that personnel can remain on board or near their stations from where they can enter the area and perform their functions intermittently. Possibly only some areas will be found to be dangerous and a sufficiently high percentage of stations will be habitable for the unit to carry on for an almost indefinite period. But if relatively complete decontamination of a ship is in order, an appreciable period of at least two weeks with good decontamination equipment and under experienced personnel must be considered as the necessary lost time.

413. Whether the decontamination measures dictated by the situation are immediate, relatively complete or both, definite steps will be taken to prevent the spread of contamination. These will consist of:

(*a*) Improvising a Change Station and executing the cleanliness doctrine as set forth elsewhere in this publication (par. 422).

(*b*) Preventing access to particularly "hot" areas by proper isolation which will include plainly marking off dangerous areas.

(*c*) Insuring a clear over-the-side drainage for water used to wash off free particles of contamination.

(*d*) Using great care in disposing of contaminated objects.

(*e*) Carrying out ventilation doctrine explained elsewhere in this publication (par. 422).

414. Induced radioactive isotopes which were previously mentioned in chapter II under the "Nature of Hazards" are important in decontamination in that familiarity with their existence and characteristics is required. Highly active immediately after the neutrons of detonation produce these isotopes, most of the important ones have the fortunate attribute of decaying rapidly into stable elements which no longer emit dangerous beta or gamma radiation and usually within 24 hours their threat becomes self-exhausted. For example, Na^{24} (Sodium ^{23} plus 1 neutron) has a "half life" of 14.8 hours after which one-half of it has resolved itself into Mg^{24} (which is stable) by radioactive emissions. In 14.8 more hours, half of the remainder also so expends its radioactivity—and so on. The bearing that this characteristic has upon decontamination is twofold. First these emissions must be avoided by repair parties and second their decay must not be over optimistically attributed to immediate decontamination washing with a result of false expectancy for the success of further measures and access without cautious monitoring. A possible third factor which should be mentioned is that competent decontamination personnel will always assume the presence of alpha emitters when gamma and beta are detected but will allow for induced radioactivity and its decay.

415. Fission products will decay roughly in proportion to the fraction $1/T^{1.3}$ where T is time in hours.

420. Personnel Decontamination.

421. Personnel decontamination is based upon the lessons gained from Operation CROSSROADS and studies made from atomic bomb casualties in Japan. The objective of personnel decontamination is identical with the objective of all radiological safety in that the ultimate goal of both is the safeguarding of personnel by preventative or by corrective measures. These will include:

(*a*) Preventing any person from being exposed to an injurious amount of external radiation and insuring that no person ingests or inhales radioactive materials by any means whatsoever.

(*b*) Corrective steps, i. e., external and internal decontamination, to minimize and alleviate the effects of any radiation received. Internal decontamination, the study of which is the responsibility of the Bureau of Medicine and Surgery, is still being investigated and information will be released by that Bureau as it becomes available.

422. In gaining the objectives of 421 (*a*) and (*b*) above, no commanding officer is restricted in promulgating orders necessary to achieve their end while still accomplishing any specific mission to which he may be assigned. As an aid, contributing to his decisions and to his promulgation of adequate orders, the following safety regulations relative to both preventive and corrective measures (personnel protection and decontamination) are advanced. Attention is invited to the applicability of these to detection as well as decontamination procedures.

(*a*) Where operationally feasible, the nationally accepted standard peacetime tolerance doses of one-tenth of one roentgen per day (0.1 r/day or its equivalent) of gamma or beta will not be exceeded. Tolerance levels of alpha (as well as wartime levels of gamma and beta) when established, will be promulgated.

(*b*) Any person receiving over-tolerance dosage will not be further exposed until succeeding days have taken up the extra dosage, unless.

(*c*) A person receives 60 r total body irradiation in which case he will not be exposed further until so authorized by BuMed or competent authority.

(*d*) Any person exposed to radioactive spray, rain or dust should immediately scrub his entire body, leave contaminated clothing in the Change Station, and report to the dispensary or the Radiological Medical Officer for examination and, if necessary, treatment.

(*e*) When operationally possible, adequate detection measures will be employed in conjunction with all decontamination procedures.

(*f*) Routine Radiological medical examination, as directed by BuMed, will be carried out.

(*g*) Film badges, supplemented by portable dosimeters if available, will be carried by all persons working in a radioactive area and a complete running record of each individual's exposure will be maintained.

(*h*) Ingestion of radioactive material will be prevented by prohibiting smoking, eating, or drinking in any contaminated area.

(*i*) High intensity areas will be plainly marked as dangerous for over —— hours —— minutes with chalk or paint. Isolation will then be maintained except for authorized persons, and not to exceed time specified.

(*j*) Complete clothing will be worn and skin exposure kept to a minimum. Change Station doctrine (pars. 327, 331) will be enforced.

(*k*) Bathing must include vigorous scrubbing of hair, hands, and fingernails. When working in contaminated areas, it is advised that fingernails be clipped short to prevent lodging of radioactive particles under them.

(*l*) Contaminated clothing will be laundered in the normal fashion but separately from other clothing. The laundry equipment used will be scrubbed with grit soap and both equipment and clothes will be monitored before returning them to normal use.

(*m*) No person with an open wound will be permitted to enter a contaminated area. Personnel acquiring an abrasion or open wound while in such an area will have the wound washed at the Change Station and report for treatment by the Radiological Medical Officer or his representative.

(*n*) Ventilation systems of contaminated ships will not be restarted without prior inspection by the Radiological Safety Officer and upon advice of the Medical Officer.

(*o*) When a certain tolerance (specified by BuMed) of radioactive isotopes or alpha emitters may be exceeded in the air, a suitable mask will be worn for protection of personnel against inhalation.

(*p*) Hands, clothing, and gloves which might have become contaminated will be kept away from the face. If swabbing in the contaminated area is necessary, swabs will not be wrung out by hand.

(*q*) Radioactive material such as contaminated debris or waste solutions used in decontamination will be dumped at sea beyond the 10-mile limit or outside the 100-fathom curve if the contamination is of high intensity irreducible to below tolerance by distributing its parts.

430. Ship Decontamination.

Ship Decontamination is based upon the lessons gained from Operation CROSSROADS and studies recently undertaken by the United States Naval Radiation Laboratory. By a Chief of Naval Operations directive, responsibility for accomplishment in connection with those tests and for research in this field has been assigned to the Bureau of Ships. The following sets forth basic procedure that are relatively firm and currently accepted. Detailed procedures and new developments will be issued by the Bureau of Ships as appropriate. Because of the confining feature of all ships, time is essential in accomplishing the immediate measures of decontamination.

431. Weather surfaces are subjected to the direct impingement of radioactivity and are thus most highly contaminated. If the contaminating particles are of the loose type deposited by cloud fall-out or base surge, the optimum condition would be a previously started, continuous film of water passing over all weather surfaces and preventing the particles from lodging in crevices and interstices. Lacking this condition, the best alternative is immediate washing of weather surfaces with a high-pressure stream of uncontaminated water. It is estimated that sea suction taken from 10 to 15 feet below the surface would not be contaminated for several minutes after a detonation even if a vessel was within several hundred yards of the burst column. For maximum effectiveness, this process of washing down the ship must begin at the highest levels and be continued down to the water line. To keep spray clear of the pumping ship and personnel it may be necessary to use own power or tugs in order that all hoses are directed downwind. This procedure may possibly reduce contamination by as much as 50 percent. A clear watershed as directly to sea as possible and perfect closure of openings that lead to the ship's interior in the section being thus processed are prerequisites. Monitoring, before and after, must be undertaken to determine results. Initial washing down may not reduce contamination to below tolerance, in which case subsequent monitoring will dictate repeating the process or taking more vigorous measures. The latter consist of the removal of closely adhering particles by chemical action or by removal of the surface to which the particles are clinging. In removal by chemical means, some fission products deposited in phosphates, carbonates, and hydroxides are soluble as citrates and some as chlorides. Therefore, either citric acid or hydrochloric (muriatic) acid, or combinations of both, may be expected to be the decontaminating solvent prescribed by BuShips upon completion of research now in progress.

(*a*) Painted surfaces are treated with a paint-removing solution. (At present a combination of 5 pounds lye, 5 pounds boiler compound, 1 pound cornstarch, and 10 gallons of water is considered the best combination.) The mixture is sprayed on the painted surface and allowed to remain 2 hours before being washed off with salt water. Residual contamination may be removed by scrubbing the surface with the same solution and hosing down.

(*b*) Bare or corroded metal surfaces should be treated by scrubbing with a solution of citric acid and/or a solution of 18° Baume muriatic acid in water followed by washing down with salt water. Should this method not suffice, wet sand blasting must be resorted to. In any case of sand blasting or scraping, the surface and the waste must be kept wet.

432. Vessels which enter or are in a body of contaminated water, such as existed within the lagoon after the underwater detonation at Bikini, will acquire some of the radioactive materials from the water. This type of contamination will consist of the lodging of radioactive materials within the salt-water systems and on the exterior hull which comes in contact with sea water. It has been found that the degree of contamination from operating for several hours in waters where the surface reading was considerably over 0.1r/day did not exceed about 0.5r/ day. The amount of contamination picked up by the salt water systems of a ship will be generally proportional to the duration of operation and the degree of contamination of the water. Experience to date indicates that this type of contamination will seldom become of operational importance and decontamination of internal systems usually may be delayed until time and materials are more readily available. It is conceivable, however, that individual cases may appear which make delay inadvisable and commanding officers will be guided by actual degrees of contamination which exist. In any case, the monitoring of systems will be necessary for the protection of personnel berthed or working adjacent to these systems. If the contaminated system is vital to the functioning or to the habitability of the ship, decontamination should proceed at once.

(*a*) Decontamination of ventilation systems is still under study and the Bureau of Ships will issue instructions when available.

(*b*) Salt water systems, heat exchangers, and evaporators may be freed from radiation hazards by the circulation of a solution of citric acid or a solution of 18° Baume muriatic acid in water throughout the contaminated units. Evaporators will be given one or more thermal-shock treatments prior to acid treatment.

433. Where vessels have a good intact coat of plastic underwater-body paint the amount of contamination retained will be minimal. Since marine growths absorb radioactive particles, their removal will greatly reduce underwater body intensities. Some removal may be accomplished with long-handled scrapers while water-borne, however, it is better accomplished by drydocking and then scraping. To prevent the creation of a potential respiratory hazard, the hull must be kept wet throughout the operation. If scraping does not reduce the contamination to a safe level, wet and blasting will be completely effective.

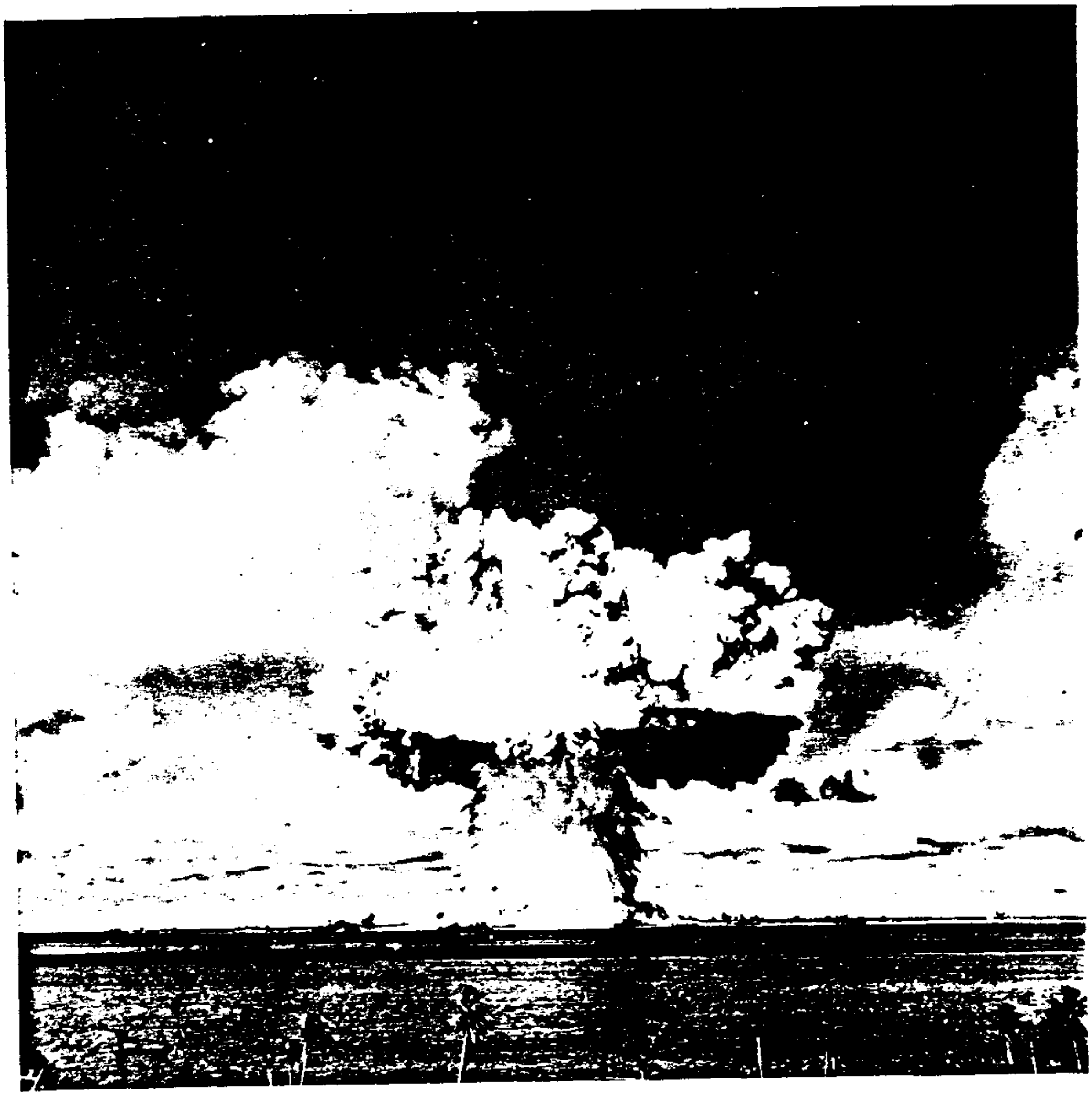

Plate IX.

434. Small boats may collect contamination on their weather surfaces, their underwater bodies and, if water-borne, in their internal piping, i. e., cooling systems. Unless of wood construction, decontamination will be the same as for ships themselves. The porous nature of wood may require a complete replacement of that material if the lye and boiler compound solution does not decontaminate sufficiently. Manila line and fenders as well as canvas canopies should be discarded if above tolerance. Propellers of water-borne boats will be scraped and washed with the muriatic acid solution.

435. Contaminated ground tackle should be treated in the same manner as corroded steel surfaces. That is, if complete washing does not suffice, a removal of the outer surface by the muriatic acid treatment or by wet sand blasting will be required.

436. Some porous materials may be expected to be replaced in the near future by substitute materials less apt to collect and hold contamination. That which is irreplaceable by a satisfactory substitute will require a shielded stowage. Decontamination being impracticable for manila, canvas, wood, and bituminous coverings, complete discarding at sea will usually be the only means of freeing a vessel of these hazards. Sinking of these materials when discarded will require expending weights.

440. Decontamination of a Naval Base.

441. Among other necessary measures, decontamination must be considered when visualizing an atomic attack against a naval base. Although no precedent exists for exactly such an attack, combinations of previous bomb effects undoubtedly will obtain. A water burst in the harbor or a low air burst will deposit contaminating materials. The first efforts of survivors will be directed toward localizing damage and toward the rescue of personnel. Detection of hazards will precede both efforts and immediate decontamination measures will be required to gain access for fire-fighting, rescue, and salvage parties. Relatively complete decontamination will take place preliminary to restoration of the area to as nearly a normal functioning status as possible. Except for differences of materials and for characteristics inherent in bases but not in ships, decontamination of bases will be essentially the same as for ships. Those features of bases and their decontamination implications which are at variance with those of ships are discussed below.

442. Rebuilding in an unaffected area will probably be advisable. The use of an alternative base for at least a month will be necessary. Some equipment and stores will be salvageable providing decontamination is effected.

443. Practically all shipboard materials are used in a naval base but in addition, the latter contains materials not encountered in ship decontamination. For example, there are greater quantities of porous materials such as concrete and wood. Although concrete is good shielding material, it absorbs contamination and presents greater difficulty in decontamination. Much greater surface removal is required and it is conceivable that the labor and waste connected with such removal may entirely obviate the gain. Among the many substances of which earth is composed there are few such as sodium, phosphorous, sulphur, etc., that absorb neutrons and thus become dangerous from induced radioactivity. However, in the case of a low air burst or an underground burst, a similar hazard to that encountered after the Alamagordo detonation will exist in that radioactive particles will be fused into the ground materials which will remain radioactive indefinitely. Only complete removal or complete denial of access can be dictated by such a condition, depending upon the requirements of the situation; i. e., the gain by removal vs. the hazard which will be proportional to the extent of contamination. The disposal of contaminated waste will present a vast problem. A temporary isolation area should be established for such disposal if sinking at sea is impracticable.

444. In most bases, fresh water is used in fire mains and for flushing purposes. Many of these mains will be ruptured, but unless the source of supply is destroyed, jumpers will reestablish the supply. The advantage of fresh water over sea water lies in the almost complete absence of sodium. Unless the presence of other minerals in unusual quantities exists, or unless contaminated by fission products, fresh water will therefore be highly acceptable for decontamination washing as well as for fire-fighting without the danger of increasing contamination. Water so used carries the radioactive particles to another location. Such redistribution, if used, must be carefully controlled and closely monitored.

445. There are some advantages among the characteristics of bases which tend favorably toward the achievement of decontamination. The confining nature of ships does not exist and refuge may be intermittently sought outside the effective range of radiation. The availability of Radsafe, Medical, and fire-fighting assistance from outside sources is a possibility. Instruments required for detection in decontamination will have previously been dispersed in stowages well shielded from initial contamination. Tide and current characteristics should be known and the natural renewal of harbor water can be anticipated. Future construction should provide for the dispersal of vital units.

450. Plane Decontamination.

The promulgation of techniques relative to plane decontamination is the responsiblility of BuAer and may be expected soon after they are resolved into firm procedures. Plane areas most contaminated will be carburetor intakes, air-cooling fins, engines, propellers, and greasy or oily surfaces contacted by contaminated air. Removal will be by washing with and without chemical solvents depending on the nature of the material contaminated and the extent of contamination. Intensities and circumstances may dictate stripping and disposal of parts or even disposal of complete planes. In any event, the protection and safety of personnel is the first consideration, and in this, paragraph 422 applies.

CHAPTER V

500. Training.

Operational Readiness in Radiological Safety depends on two types of training: (a) an Operational Instruction Program, and (b) Operational Exercises.

510. The Operational Instruction Program is again divided into (1) General Indoctrination of All Hands, and (2) Specialized Instruction. The competence of the Radiological Safety Officer largely depends upon his ability to administer General and Specialized Instruction as directed by the Commanding Officer and by the Damage Control Officer.

511. General Indoctrination of All Hands will be conducted in a manner comparable to the dissemination of general knowledge damage-control information using the lecture and quiz methods. It will include:

(*a*) General Knowledge of the Nature of the Hazards (ch. II).

(*b*) General Knowledge of Detection (ch. III), including capabilities and limitations of the various types of instruments especially the film badge and dosimeter which apply to all hands.

(*c*) General Knowledge of Decontamination (ch. IV), including Safety Measures applicable to all hands.

(*d*) The place of Radiological Safety in relation to the unit organization and individual responsibilities in connection with this type of attack.

(*e*) A suggested outline for a General Indoctrination lecture is included (p. 5–9). It is suggested that in addition to this lecture, the RadSafe film (Training Film #MN 5367 B) be shown.

512. Specialized Instruction.

(*a*) Specialized instruction of the Radiological Safety Officer himself will be largely self-administered, but the Commanding Officer should be cognizant of the constantly changing nature of this new science and the need of the Radiological Safety Officer's keeping abreast of new techniques and developments in this field. Sources of information are listed in chapter I. In addition, the RadSafe School will maintain a mailing list of graduate officers for the purpose of disseminating new developments insofar as security restrictions permit. Such information will augment or parallel that promulgated by the Chief of Naval Operations and by cognizant bureaus. It is desirable that officers nominated to the Damage Control School and its adjunct, the RadSafe School, have the qualification of a previous course comparable to Naval Academy physics. In addition, they will be better prepared if they have completed the BuPers Correspondence course in Nuclear Physics.

(*b*) It will be the duty of the Medical Officer to learn techniques and maintain standards specified by BuMed for the personnel for which he is responsible. In this duty, his responsibilities to the Commanding Officer and his relationship to the Damage Control Officer are identical to those existing in connection with preparing for and treating any personnel damage.

(*c*) Although eventually Radiological Safety Monitors will be trained in special BuPers schools, such schools are at present still in the planning stage. Consequently, specialized training required to produce adequate enlisted operators from among repair party personnel will be conducted within each unit by the Radiological Safety Officer. An outline of a recommended course and the division of the material to be covered including practical exercises into 28 periods follow:

(1) Training course for Radiological Safety Monitors:
- (I) Background and Nature of the Hazards. Use General Indoctrination Lecture, parts I and II.
- (II) Detection.
  - (A) Theory of measuring devices.
    - (1) Explanation of atom and molecules.
    - (2) Ionization.

(II) Detection—Continued.
- (A) Theory of measuring devices—Continued.
  - (3) Electroscope.
  - (4) Geiger-Muller tube.
  - (5) Darkening of film.
  - (6) Applications of Geiger tube. (Ion Chamber, Proportional Counter, Geiger Counter.)
- (B) Instruments—specific types.
  - (1) X–263 } or instruments in use that supersede these.
  - (2) 247 }
  - (3) Dosimeter, proteximeter (if aboard).
  - (4) Scaling Counters.
- (C) Film badges and photographic dosimetry.
- (D) Figuring intensity and time tolerance.

(III) Decontamination.
- (A) Reiteration of areas susceptible to contamination.
- (B) Exterior decontamination.
  - (1) Immediate measures.
  - (2) Later, more thorough steps to be taken.
- (C) Interior decontamination.
  - (1) Ventilation.
  - (2) Heat. exchangers.
  - (3) Evaporators.
  - (4) Piping.
- (D) Personnel decontamination.

(IV) Integration into ship's organization.
- (A) Damage Control Parties.
- (B) Specific duties of CIC.
- (C) Organizational requirements for all phases of decontamination.
- (D) Functions of RadSafe in advisory capacity.

(V) Safety Regulations.

(VI) Explanation of drills.

(2) Periods, division into for training.
- (1) Background and nature of hazards (Repeat this period as necessary).
- (2) Explanation of atom and molecule; ionization.
- (3) Electroscope, Geiger tube.
- (4) Ion Chamber, Proportional Counter, Geiger Counter.
- (5) Photographic dosimetry.
- (6) X–263 (or similar type instrument).
- (7) X–263 (or similar type instrument).
- (8) 247 (or similar type instrument).
- (9) Dosimeter, proteximeter, scalers.
- (10) Review.
- (11) Practical exercise—instruments (figure intensity and time tolerance).
- (12) Practical exercise—instruments (figure intensity and time tolerance).
- (13) Practical exercise—instrument calibration.
- (14) Practical exercise—instrument calibration.
- (15) Practical exercise—instruments Basic drill.
- (16) Practical exercise—instruments Basic drill.
- (17) Indoctrination and decontamination—Ship contamination; background data.

(2) Periods, division into for training—Continued.
  (18) Exterior decontamination.
  (19) Decontamination of boats, ground tackle.
  (20) Interior decontamination.
  (21) Personnel decontamination.
  (22) Review.
  (23) Decontamination drill.
  (24) Details of ship's RadSafe Organization.
  (25) Safety regulations.
  (26) Review.
  (27) Drills.
  (28) Drills.

(*d*) Electronics technician mates will be capable of material upkeep of instruments providing adequate spares are supplied. The circuits of these instruments are relatively simple compared to those in radar equipment. However, BuShips may be expected to provide instruction booklets whenever more complicated instruments are issued (par. 321 (*b*)).

(*e*) The plotting of contours of equal intensity in connection with air and sea monitoring will introduce only slight variations in standard procedures to CIC. Of these variations, those which are not obvious from the General Indoctrination Course are:
(1) Relationship between aerology and air diffusion and transfer rates.
(2) Relationship between oceanography and water diffusion and transfer rates.

Reports of resultant plots required by flag and commanding officers will depend upon the nature of the information obtained and the mission to be accomplished. CIC personnel will be instructed by the Radiological Safety Officer in (1) and (2) above.

(*f*) Repair-party personnel will require some specialized instruction in decontamination processes.

513. Section 150 of chapter I lists some tactical implications which indicate an increased need for proficiency in certain ship tactics. Because existing USF publications provide formations of various intervals and distances between units and because existing exercises in ship control and seamanship are adequate if given special emphasis, no specific tactical exercises other than avoidance of contamination are included in this publication. However, as circumstances permit, tactical commanders will be expected to conduct such normal exercises with a view toward achieving and maintaining high standards in:
(*a*) Formation changes to gain increased distances and intervals between units.
(*b*) Prompt action of ship control personnel in the avoidance of contamination.
(*c*) Alongside shiphandling for the purpose of evacuating presonnel.
(*d*) Towing with the objective of removing a damaged unit from a contaminated sea area.

520. Basic Operational Exercise.

(*a*) Especially in those exercises that visualize an atomic burst it is intended that as a result of drill, correct procedure will automatically follow and panic will be minimal. However, it is easily imaginable that a large chemical explosion in a harbor could cause some hysteria with a disruption of organization unless immediately identified as non-atomic. Consequently, in the execution of such exercises, emphasis should be placed upon the fact that the detonation has been reliably identified as atomic and the following important steps should be expedited:
(1) Quick and reliable determination of how much radiation the ship as a whole has received.
(2) Same for individual crew members.

(*b*) Basic Operational Exercises follow:

Training Exercise 85F-1-R

BASIC DRILL IN INDOCTRINATION OF ALL HANDS

1. Purpose:
   (*a*) To evaluate the performance of All Hands immediately following an atomic burst.
2. Situation:
   (*a*) Facilities and services.
   No outside facilities and services are required.
   (*b*) The problem assumes that:
   (1) A bomb has been detonated underwater within 1,000 to 3,000 yards from the vessel and has been reliably identified as atomic.
   (2) All personnel have received general indoctrination in Radiological Safety.
   (*c*) Actual initial set up.
   Ship in Condition 2 and Material Condition Y(B).
   (*d*) Reference: Chapters I and II, USF85.
   (*e*) Preparation:
   (1) Exercise problem.
3. Procedure:
   (a) Ship and personnel take appropriate action in accordance with information disclosed by observer.
4. Evaluation:
   (a) Judge performance and readiness on the basis of:
   (1) Speed and completeness of exposed personnel taking cover and gaining shielding.
   (2) Speed and correctness of ship control party action.
   (3) Speed and completeness of ship closure.
   (4) Speed in donning gas masks.
   (5) Speed and completeness of measures to determine total ship and individual exposure.

Training Exercise 85F-2-R

USE OF CHANGE STATION

1. Purpose:
   (*a*) To evaluate the general knowledge of All Hands in respect to Change Station procedure.
2. Situation:
   (*a*) Facilities and services:
   No outside facilities or services are required.
   (*b*) The problem assumes that:
   (1) An underwater atomic burst has been detonated nearby the ship so that a number of exposed personnel have been covered with radio-active spray. The burst has been reliably identified as atomic.
   (2) The crew has received general indoctrination in Radiological Safety.
   (*c*) Actual initial set-up:
   (1) Ship in Condition I Material Condition Z (A).
   (2) No Change Station has been designated.
   (*d*) Reference: Chapter III and IV USF 85.
   (*e*) Preparation:
   (1) Exercise problem.

3. Procedure:
   (a) Crew members selected at random by observer take appropriate action toward self-decontamination.
4. Evaluation:
   (a) Judge performance and readiness on the basis of:
      (1) Speed and correctness of designating the most uncontaminated and most readily available washroom as Change Station, disseminating this information and setting up its operation.
      (2) Speed, correctness and thoroughness of action taken by each contaminated individual.
      (3) Functioning of Change Station personnel, including medical.
      (4) Functioning of measures to determine exposure of individuals.

Training Exercise 85F–3–R

ATOMIC ATTACK

1. Purpose:
   (a) To evaluate the performance of All Hands in case of an atomic attack from which contamination and casualties are moderate.
2. Situation:
   (a) Facilities and services:
      No outside facilities or services are required.
   (b) The problem assumes that:
      (1) An atomic bomb was detonated in close proximity to the ship such that there is moderate contamination in which the hazards are localized but with most ship control and gunnery stations sufficiently habitable to permit at least intermittent occupancy and functioning.
      (2) Personnel have been instructed as to action to be taken in case of an atomic attack.
      (3) Radiological Safety Monitors have been trained and detection instruments have been allocated and are on board. (If instruments are not available, locations and intensities will be prescribed by observer).
   (c) Actual initial setup:
      Radioactive samples of various intensities (in the form of radium buttons) have been concealed in various points about ship to denote areas of contamination. Assume multiple values of their intensity. (As in (b) (3) above, observer may prescribe locations and intensities).
   (d) Reference: Chapters III and IV, USF 85.
   (e) Preparation:
      Standard exercise problem.
3. Procedure:
   Ship take or simulate appropriate action in accordance with information disclosed by observer.
4. Evaluation:
   (a) Judge performance and readiness on the basis of:
      (1) Maneuvering of ship to gain uncontaminated water.
      (2) Speed in determining total ship radiation received.

4. Evaluation—Continued.
   (a) Judge performance and readiness on the basis of—Continued.
      (3) Speed and organization in detection of contaminated areas and the carrying out of isolation procedures, i.e., marking, restricting access, personnel monitoring, personnel distribution, use of change station first aid procedures, etc.
      (4) Coordination of decontamination with the general problem.

Training Exercise 85F–4–R

DETECTION AND THE ESTABLISHMENT OF TOLERANCE PERIODS

1. Purpose:
   (a) To evaluate the performance of Radiological Safety Personnel in detecting radiation and in establishing time limits for proximity to various intensities.

2. Situation:
   (a) Facilities and services:
      No outside facilities or services are required.
   (b) The problem assumed that:
      (1) Certain areas about the ship have become radioactive because of an atomic burst.
      (2) RadSafe Monitors have been trained.
      (3) Sources, in the form of radium buttons, are readily available.
      (4) Detection instruments have been allocated and are on board.
   (c) Actual initial set-up:
      Radioactive samples of various intensities have been concealed in the drill area. (Assume multiple values if desirable.)
   (d) Reference: Chapter III, USF 85.
   (e) Preparation:
      (1) Issue Geiger Counters, film badges and dosimeters.
      (2) Drill area markings to restrict nonparticipating personnel.
      (3) Samples to be hidden prior to drill.

3. Procedure:
   Check calibration of instruments and take appropriate action in accordance with information disclosed by observer. Fill out applicable parts of BuShips-BuMed Form #1.

4. Evaluation:
   (a) Judge performance and readiness on the basis of:
      (1) Instrument calibration and state of repair.
      (2) Ability of participants to locate sources.
      (3) Proficiency in establishing safe time limits at various intensity levels.

Training Exercise 85F–5–R

EVALUATION OF SITUATION

1. Purpose:
   (a) To evaluate the efficiency of the Radiological Safety organization in estimating the composite situation after an atomic attack.

2. Situation:
   (a) Facilities and services:
      No outside facilities or services required.
   (b) The problem assumes that:
      (1) A burst has occurred near the ship possibly contaminating certain areas of the ship.

2. Situation—Continued.

(b) The problem assumes that—Continued.

(2) Monitors have been trained in covering normal routes to gain information required for the composite report of the entire ship as quickly as possible and giving precedence to coverage of vital stations.

(3) Structural damage, communication failures and areas of high intensity will be prescribed by the observer to cause variations in normal procedure.

(c) Actual initial set-up:

(1) Ship in Condition 1 Material Condition Z (A).

(2) Various areas of the ship have been barricaded to simulate displaced or distorted structure.

(d) References: Chapter III, USF 85.

(e) Preparation:

(1) Exercise problem.

3. Procedure:

(a) Repair parties take or simulate appropriate action in accordance with information disclosed by the observer.

4. Evaluation:

(a) Judge performance and readiness on the basis of:

(1) Speed and completeness of measures to identify burst as atomic.

(2) Speed, completeness, conformance with safety precautions and adaptation to casualties of the Radiological Safety organization in their coverage of all areas.

(3) Recording and evaluating intensities on a rough plan of the ship and making essential reports to the Commanding Officer and other departments.

Training Exercise 85F–6–R

BASIC DRILL IN DECONTAMINATION

1. Purpose:

(a) To evaluate the performance of repair parties in decontamination after an atomic bomb attack.

2. Situation:

(a) Facilities and services:

No outside facilities or services are required.

(b) The problem assumes that:

(1) An atomic bomb has been detonated below the surface 1,000 to 3,000 yards from the vessel. Ship control action has carried ship to uncontaminated water.

(2) Radiological Safety Monitors have been trained in their duties and repair parties have been instructed in decontamination measures.

(c) Actual initial set-up:

Ship in Condition 1 Material Condition Z (A).

(d) References: Chapter IV, USF 85.

(e) Preparation:

(1) Exercise problem.

3. Procedure:

(a) Repair parties take or simulate appropriate action in accordance with information disclosed by the observer.

4. Evaluation:
   (*a*) Judge performance and readiness on the basis of:
      (1) Adequacy of measures taken to identify burst as atomic.
      (2) Speed, completeness and conformance with safety precautions in applying uncontaminated water to weather surfaces.
      (3) Speed and effectiveness in ridding the ship of simulated high radioactivity using complete decontamination measures on both painted and unpainted metal surfaces.
      (4) Cooperation between monitors and rest of repair party.

Training Exercise 85F–7–R

PLOTTING OF RADIOACTIVE SEA AREA

1. Purpose:
   (*a*) To evaluate the performance of CIC personnel in tracking and plotting a radioactive sea area given prepared values of intensities, bearings and ranges.

2. Situation:
   (*a*) Facilities and services.
      No outside facilities or services are required.
   (*b*) The problem assumed that:
      (1) An underwater atomic burst has been detonated in the area and this CIC has been assigned the task of tracking and defining the radiological sea area.
      (2) CIC personnel have been instructed by the Radiological Safety Officer in the plotting of lines of equal intensity.
   (*c*) Actual initial setup:
      CIC and Communications in Condition 1.
   (*d*) References: Chapter III, USF 85.
   (*e*) Preparation:
      (1) Exercise problem.

3. Procedure:
   (*a*) CIC will plot the reports of various intensities, ranges and bearings as furnished by the observer. Red and blue lines of equal intensity will be included in this plot.

4. Evaluation:
   (*a*) Judge performance and readiness on the basis of:
      (1) Speed, efficiency and accuracy of plotting of intensity contours by CIC.
      (2) Speed in formulating reports to OTC relative to avoidance of sea areas.

Training Exercise 85F–8–R

CLOUD TRACKING AND PLOTTING

1. Purpose:
   (*a*) To evaluate the performance of CIC personnel in tracking a cloud formation given prepared values of intensities, bearings, ranges and altitudes.

2. Situation:
   (*a*) Facilities and services.
      No outside facilities or services are required.
   (*b*) The problem assumes that:
      (1) An atomic air burst has been detonated in the area and this CIC has been assigned the task of tracking the cloud of radioactive dust, fission products and unfissioned particles of the bomb.

2. Situation—Continued.
   (*b*) The problem assumes that—Continued.
      (2) CIC personnel have been instructed by the Radiological Safety Officer in probable cloud movement.
      (3) There is a well defined cloud that may be followed and tracked by planes and/or ships. Periodic reports of location and intensities will be assumed.
      (4) Ballistic wind data has been received.
   (*c*) Actual initial setup:
      CIC and Communications in Condition 1.
   (*d*) References: Chapter III, USF 85.
   (*e*) Preparation:
      (1) Exercise problem.

3. Procedure:
   (*a*) Reports of various intensities will be furnished by the observer to CIC at different ranges, bearings and altitudes.

4. Evaluation:
   (*a*) Judge performance and readiness on basis of:
      (1) Speed, efficiency and accuracy of plotting done by CIC.
      (2) Speed in formulating reports to OTC relative to avoidance of cloud and cloud fall-out.

530. General Indoctrination Lecture (2 hours).

I. Introduction.
   A. The purpose of this lecture is to familiarize all shipboard personnel with the hazards of atomic warfare and with the measures prescribed for defense.
   B. A general discussion of bursts.
      1. Background data.
      2. A description of air and shallow water bursts.
   C. Tactical applications of atomic warfare.
      1. Methods of delivery:
         a. Aircraft, for ranges of thousands of miles.
         b. Guided missiles, for ranges of a few hundred miles.
         c. Clandestine (Trojan Horse), for seaports, canals, and airports.
         d. Clandestine, sabotage.
         e. Torpedo.
         f. Mine.
      2. Units most likely to be attacked:
         a. Strategic locations (large seaports, urban industrial centers, etc.).
         b. Bases.
         c. Amphibious operations.
         d. Any relatively immobile concentration of important ships.
      3. Radiological warfare as a possibility.

II. Burst phenomena and their effects.
   A. Blast effects on:
      1. Material.
      2. Personnel.
   B. The "ball of fire."
   C. The types of nonionizing radiation and their effects.
      1. Infra-red rays.
      2. Visible light.
      3. Ultra-violet rays.

II. Burst phenomena and their effects--Continued.
- D. The results of exposure to neutrons and gamma rays.
  1. Immediate physiological hazards.
  2. Induced radioactivity.
- E. The principal contamination results from unfissioned parts of the bomb and fission products.
  1. A discussion of the distribution of these particles by various types of bursts.
  2. The resulting radioactivity and the effects.
     - *a*. Beta particles.
     - *b*. Alpha particles.
     - *c*. Gamma rays emitted.

III. A general explanation of detection.
- A. A demonstration of the currently used instruments.
- B. Instructions in the use of film badges and the dosimeter.
- C. The capabilities and limitations of the above.

IV. Shipboard defense.
- A. RadSafe integrated into the Damage Control organization.
- B. All hands required for decontamination.
  1. Procedures immediately after attack.
  2. Later, more thorough decontamination:
     - *a*. Weather surfaces.
     - *b*. Underwater body.
     - *c*. Internal piping.
     - *d*. Evaporators.
     - *e*. Heat exchangers.
- C. All hands will have functions in various drills incorporating Radiological Safety.

V. Safety Regulations applicable to All Hands.